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Chances for Engineers Bettered by FAC Aviation Ideas

By Edward P. Warner
Vice-Chairman, Federal Aviation Commission

As Told to Norman G. Shidle

Underwood & Underwood

THERE is "no evidence that American industrial organization or American engineering treatment applied to the development of aircraft are in any way inferior in capacity or in airworthiness to those of the rest of the world," the Federal Aviation Commission concluded in its now much-publicized report which contains many elements of special significance to aeronautic and automotive engineers.

Certain recommendations of this report, if adopted, may bear heavily and favorably on the business lives and technical opportunities of engineers. When the Commission urges that *nothing* be allowed to interfere with the steady development and completion within five years of the aircraft expansion programs recently presented by the War and Navy Departments, for example, it recommends an activity which can hardly fail to bring better chances for development and application of the sound ideas of aeronautic engineers in the immediate future. The Commission's express advice that increased research work in aeronautics be encouraged and that the Department of Commerce and the National Advisory Committee for Aeronautics should have a special fund for use in stimulating development of improved types of aircraft for private use, if followed, would improve further the opportunities for constructive technical work. Numerous

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Edward P. Warner

Mr. Warner, a past-president of the S.A.E. and formerly Assistant Secretary of the Navy for Aeronautics, has just completed seven months' work as vice-chairman of President Roosevelt's important Federal Aviation Commission.

In the accompanying interview, he interprets the conclusions of that Commission's recent report in terms of its significance to automotive engineers in general and to his fellow members of the S.A.E. in particular.

American Engineers Lauded

The report of the Federal Aviation Commission, based on an intensive investigation of *facts*, contains many statements reflecting high praise for the aeronautic engineering profession in America, leading members of which are constantly active in S.A.E. affairs. Typical of such statements are the following:

"American air transport equipment as developed in the last three years is generally recognized as occupying a position of world leadership."

* * *

"In respect to those types of military equipment upon which we have concentrated special attention, there have been developed products unexcelled, and, in many cases, unequalled elsewhere."

* * *

"Whatever line of development is made the subject of concentrated attention here . . . will progress at least as briskly as under any other flag."

* * *

". . . nowhere else are passengers, mail and goods carried with such regularity and speed, by day and by night, with such comfort and convenience to the user of the service on anything like so broad a network as that provided by our major air lines."

* * *

". . . for the qualities of most of the Army Air Corps aircraft and engines, we have only praise."

other ideas advanced by the Commission may well be found helpful in this respect.

In attempting to interpret the findings of this Commission from an engineering viewpoint, it is pertinent to note that its membership represented a variety of experience. Two of its members had been engineers; one had been a lawyer; one had been concerned principally with public affairs; and the fifth with labor and personnel problems. On occasion every member had to attempt to think as a lawyer to the best of his ability; then abruptly he had to turn to subjects that required him to think as an engineer. During those periods of the Commission's work in which its members sought the engineering point of view, the keynote of their thought was expressed in two phrases which appear in the report:

(1) "It is upon current experimental appropriations and upon the wisdom with which they are expended that the quality of our aircraft of a few years hence are dependent" and (2) "the best qualities of present day aircraft are preeminently due to organized research work, and the work done by the Government in that field has paid for itself repeatedly in the improved service that aircraft has been able to render as a result."

The Commission came readily to unanimous agreement as regards the controlling importance of the role played by the engineer; the vital need for increased laboratory research and development; and the credit due to American aeronautical engineers.

The Commission concluded, in fact, that "American air transport equipment as developed in the last three years is generally recognized as occupying a position of world leadership.

"From all that we can discover," the report continues, "of the record at home and abroad, nowhere else are passengers, mail and goods carried with such regularity and speed, by day and by night, with such comfort and convenience to the user of the service as on our major airlines. . . . In respect of those types of military equipment upon which we have concentrated special attention, there have been developed products unexcelled, and, in many cases, unequalled elsewhere. . . . Whatever line of development is made the subject of concentrated attention here and given suitable Governmental support will progress at least as briskly as under any other flag."

The Commission found, in other words, that greater opportunity for the exercise of existing technical skill, rather than increase of skill in itself, is the pressing need. Both for development of aeronautic equipment and for research, in fact, money appeared to be the crux of the problem. The Commission's report indicates, for example, its conviction that larger appropriations could be used to great advantage for the experimental sections of the Army and Navy and in the budget for the National Advisory Committee for Aeronautics.

It was not the responsibility of the Federal Aviation Commission to examine into the minute details of design. Its concern was broadly with the adequacy of present organizations; with the suggestion of ways in which aviation may best be developed; and with comparison of the product of American aeronautic engineers to that of the rest of the world.

As noted previously, the Commission was able to speak in flattering terms about American aviation on all these scores.

Yet, its investigations did lead it to definite criticism of some American development as lacking in breadth. As a result, it urged the Government to call immediately for engines of larger power than any that now exist; for increasing provision for high-altitude supercharged engines in service; and for a more active campaign of development of Diesel engines for aircraft use.

While America has taken the lead in all of these engineering realms, the Commission found it to be in danger of falling behind in the future as a result of too casual an attitude by Governmental authorities toward these particular phases of development. The result of such an attitude is insufficient appropriations for carrying on the experimental studies which definitely should be continued for both the Army and the Navy.

Lack of appropriations is particularly lamentable in view of the clear indication that American engineering talent is available to utilize constructively and for the economic good of the country funds devoted to such research work.

The Commission recognized, of course, that it would take years to bring to readiness for service new technical undertakings of the magnitude of those suggested. That made it seem all the more urgent that work be started without delay.

Important among the programs which should get immediate attention, the Commission thinks, are development of service engines for 1200 hp. to 1500 hp. normal rating and of high-powered, aircraft Diesels for transport, bombing and patrol service.

The need for high-powered engines is simply an echo of

the demand for higher performance to meet military needs. Increase in power means increased speed. If a single-engined fighter is to be put up to 300 m.p.h. or better, and if the twin-engined bomber is to reach 250 m.p.h. or more with a 2000 lb. bomb, powerplants of more than 1000 hp. each are almost indispensable. The form such engines should take, and whether they should be air-cooled or liquid-cooled, is for further studies by the engine-building industry to determine.

The growing interest in trans-oceanic flight, both for transport and for possible military operations, makes fuel economy bulk larger in importance than ever before. The promised fuel saving of the Diesel might mark the difference between commercial success and a payload limited to cover the cost for services on the longest of these routes.

Immediate commercial demand for the aircraft Diesel, however, is too limited to justify any aircraft manufacturer in assuming all the costs of a really intensive development program. If such an engine is to be pressed forward with the speed that the Commission recommends, it will probably have to be through liberal Governmental backing by experimental orders and by continued research on design fundamentals in the laboratories of the National Advisory Committee for Aeronautics.

To gage properly the significance of the various recommendations of the Federal Aviation Commission, it is important to recognize that its function was in no sense political. It was a non-partisan body, directed by the law creating it to study air policy and the factors affecting it, and to recommend the course best adapted to promoting the protection of the public safety in aircraft.

The Commission undertook its work in that spirit. The part of the work that was ours has been completed. Recommendations have been presented. While I naturally hope, as I presume my colleagues do, that our work will meet with favor and be accepted as a foundation for further development of American air policy, that is for public opinion to debate and for Congress and the President to determine.

Aviation Commission Gets S.A.E. Views

Meeting on Dec. 18, the Council of the Society approved a letter to the Hon. Clark Howell, chairman, Federal Aviation Commission, embodying the views of the Society on certain phases of the Federal aviation program.

The opinions in the letter represent the consensus of a committee of the Society's aircraft representatives, and were sent to the Federal Aviation Commission in answer to a request that the Society should present its views for the record.

The text of the letter, as approved by the Council and transmitted and signed by President D. G. Roos, is printed herewith.

December 18, 1934

Honorable Clark Howell,
Chairman, Federal Aviation Commission,
Washington, D. C.

Dear Mr. Howell:

The Society of Automotive Engineers appreciates the privilege of presenting its view in reply to your letter of July 13, 1934.

The Society of Automotive Engineers is an organization whose purposes are to provide opportunities for engineers to present new technical knowledge and to inform its members of technical progress in the automotive industry. The Society has a large membership of engineers and scientists who are associated with aeronautical engineering (embracing aircraft, engines and accessories) and a considerably larger number are associated indirectly with aeronautical engineering but vitally involved in its progress.

The Society is of the opinion that future progress in aeronautics, both commercial and military, depends on the trained scientists and engineers, and that in the determination of a national aviation policy due consideration should be given to the encouragement and the welfare of scientists and engineers engaged in aeronautical research and in the aircraft industry.

The following are the recommendations of the Society of Automotive Engineers with reference to the maintenance and encouragement of a group of trained aeronautical scientists and engineers as a safeguard to the future development of aviation in the United States:

Recognition of Design and Proprietary Rights. To stimulate private initiative and to place aircraft organizations on a sound financial basis, it is necessary to recognize proprietary rights. Procurement regulations should be drawn in such form that proprietary rights are respected, and the initiative and pioneering efforts of engineering organizations are financially rewarded. To insure the continued development of aviation in this country, aircraft manufacturing organizations should maintain strong technical and engineering staffs. The recognition of design and proprietary rights would in a large measure insure the maintenance by large aircraft manufacturers of competent engineering staffs, and would stimulate and encourage initiative and pioneering effort on the part of each company in the production of new aircraft.

Patent Rights in Experimental Contracts. The patent clauses in experimental contracts of the Government should be carefully reviewed so that the rights of the manufacturers are fully safeguarded. The protection of the manufacturer's patent rights would stimulate the cooperation of manufacturers in governmental experimental programs. The patent and reproductive rights of the Government for its own use should be limited to those patents which result directly from experimental projects under contract, and for which adequate reimbursement for such improvements and reproductive rights is included. The effect of very broad patent clauses in experimental contracts which grant to the Government full rights to have made or to make the articles involved in the project, is to deter the engineering staff of the manufacturer from giving full cooperation with the maximum initiative. This recommendation is made with a view to providing a protection which will stimulate the development of competent engineering organizations by aircraft manufacturers.

Patent Rights in Production Contracts. In production contracts obtained as a result of competitive bidding, the Government pays only a fair price for the articles produced. The Society recommends the elimination of patent clauses in production contracts.

Government Competition with Industry. The Society of Automotive Engineers recommends that the Government not enter into competition with the industry in the development of experimental projects that are to serve the same purpose; and that the Government not engage directly in competition with the aircraft industry in the manufacture of aircraft. An adequate aircraft industry is necessary to our national defense, and the efforts of the Government should be extended to building up this industry, especially competent engineering staffs. Any competition by the Government in experimental development cannot fail to weaken the industry. The functions of the industry should not be limited merely to production, but should include pioneering development requiring trained technical personnel. In order that an incentive may be provided for the maintenance of organizations of such personnel, the Government should not enter into direct or indirect competition. Every encouragement should be given to the development of new ideas and new designs, and this can only be accomplished by the maintenance of trained engineering staffs by the various units of the industry.

Research, Experimentation, Education. The Society of Automotive Engineers heartily endorses the research activities of the Government, particularly those of the National Advisory Committee for Aeronautics, and recommends that this activity be supported by adequate appropriation, for the energetic pursuit of fundamental aeronautical research and for the prompt dissemination of the results of such studies for the benefit of military and commercial aeronautical engineering progress. The Society recommends the maintenance of a well-equipped and well-staffed engineering division of the Army Air Corps, for carrying on engineering experimentation in aeronautics, for the development of specifications for military aircraft and for testing and judging the merits of aircraft or aeronautical parts submitted for consideration; for maintenance of a similar activity by the Navy Department of the Naval Aircraft Factory at Philadelphia, and the maintenance of the facilities of the National Bureau of Standards for conducting investigations principally in the fields of physics and metallurgy.

The Society further recommends the encouragement of educational institutions in the training of research and production engineers and the conduct of aeronautical research and experimental investigations in their laboratories.

Very truly yours,

SOCIETY OF AUTOMOTIVE ENGINEERS, Inc.
(signed) D. G. Roos
President.

Nominations for Vice-President

ON Jan. 7, 1935, the S.A.E. Council passed a resolution outlining procedure to be followed in the matter of electing a vice-president of the Society representing the Transportation and Maintenance Engineering Activity for 1935. This resolution was printed in full on pages 26 and 27 of the February, 1935, issue of the S.A.E. JOURNAL.

Following is the nomination for vice-president of the S.A.E. representing the Transportation and Maintenance Engineering Activity for 1935 as published on page 27 of the February, 1935, issue of the S.A.E. JOURNAL:

T. C. Smith

Engineer, Motor Vehicles and Construction Apparatus, American Telephone and Telegraph Co.

The above nomination was filed for the 1934 Transportation and Maintenance Activity Nominating Committee by F. C. Horner, chairman; B. J. Lemon; A. R. Platt; Henry Dakin, alternate; and Pierre Schon, alternate.

Subsequent to publication of the above nomination, the following additional nomination for vice-president of the S.A.E. representing the Transportation and Maintenance Engineering Activity for 1935 has been submitted to the Secretary by a Special Professional Activity Nominating Committee for insertion on the official ballot. This Committee was organized in accordance with the provisions of Paragraph 47 of the Society Constitution and the procedure required by the Council resolution of Jan. 7, 1935, referred to above.

Fred C. Patton

Assistant General Manager, Los Angeles Motor Coach Co.

The members comprising the Special Professional Activity Nominating Committee which submitted this nomination were:

W. B. Hurley, P. Altman, R. J. Waterbury, L. A. Majneri, H. T. Youngren, C. H. Allen, N. D. Howell, H. B. Shoemaker, E. H. Kelley, L. A. Chaminade, S. C. Schwarz, Herman E. Winkler, Louis Schwitzer, Stanwood W. Sparrow, Roy E. Cole, Joseph A. Packard, Lee Oldfield, Chas. C. Merz, H. W. Drake, G. P. Texada, E. W. Higgins, William Jack, C. R. Paton, Marsden Ware, W. R. Griswold, E. H. Smith, F. R. McFarland, Henry Krebs, Edwin F. Storey, E. C. Wood, Ulysses A. Patchett, Arthur B. Domonoske, Elliott G. Reid, L. M. K. Boelter, C. J. Vogt.

Fuel Injection as Applied to Aircraft Engines

J. F. Campbell
Chief, Carburetor Unit, Power Plant Branch,
Matériel Division, U. S. Army Air Corps

THIS paper covers in a general way the development of a complete fuel injection system, including fuel injector, discharge nozzle, control system, fuel system, etc., and the application of the system to Pratt and Whitney Wasp engines, Wright Aeronautical Cyclone, Curtiss Conqueror and Allison V-1710 engines, also the installation of the Pratt and Whitney Wasp engine in service airplanes and the performance obtained with the system.

THE inherent unsatisfactory performance obtained with carburetors during the execution of tactical maneuvers prompted the starting of the development of mechanical metering by the Air Corps on June 10, 1925. Knowing that the float mechanism of the carburetor was largely responsible for the unsatisfactory performance, original studies were made employing carburetor bodies, throttles and discharge nozzles, but with metering controlled by some device which would not change its metering characteristics during the execution of tactical maneuvers. Since load compensation requires the fuel flow to vary approximately in direct proportion to engine r.p.m., fuel transfer pumps in service which possessed this characteristic were used for metering fuel during the preliminary studies. Metering tests with a bellows pump, gear pump, piston pump, centrifugal pump and a system composed of a variable bypass (by metering pin) and fixed orifice in conjunction with the gear pump, disclosed that each had characteristics which made it unsatisfactory, except the piston pump. It was concluded that a positive displacement, piston type pump with means for adjusting the stroke would constitute one which was basically correct for aircraft engines.

Numerous devices and methods for obtaining variation in the stroke of the piston type pump involving linkages, cams, etc., were considered. A wobble plate with provision for controlling the angle of the plate was considered satisfactory and a piston type pump incorporating this feature was designed and constructed by the Air Corps. This pump was installed on a V-1150 type engine equipped with rotary induction system, since the performance of this engine with carburetor installed at the suction side of the supercharger was poor. The installation was made with no attempt to synchronize the pump discharges with the suction impulses from the cylinders, the drive being taken from the accessory section at the rear of the engine. The pump discharge was directed to the center of the supercharger impeller from an open nozzle. Results of tests conducted during 1926 and 1927 with this basic system and modifications thereto, indicated that a mechanical linkage employed to connect the stroke adjusting lever of the injector and the air throttle could be employed to obtain mixture strengths which would satisfy the engine requirements throughout the operating range. The use of a barrel throttle in place of the conventional butterfly type was found to permit the use of mechanical linkage without employing a cam and was, therefore, preferred. Later tests with other engines disclosed that the mixture strength requirements could not be satisfactorily met without the use of a cam, and as the barrel throttle was unsatisfactory from a service standpoint, no further applications of it were made. Acceleration was unsatisfactory until a charge was injected by a pump operated by the movement of the throttle. While distribution was better than with the carburetor, it was believed that still better distribution of fuel could be obtained if the fuel was introduced near the intake port of each cylinder.

[This paper was presented at the Annual Meeting of the Society, Detroit, Jan. 15, 1935.]

Historical

A variable stroke piston type injector of the basic design, invented by M. G. Chandler, was built to Air Corps requirements by the Marvel Carburetor Co. of Flint, Mich., and furnished to the Division during 1927. It was used in studying nozzle arrangements for injecting fuel into the intake port of a single cylinder engine. These studies, which were made from late in 1927 to July, 1928, disclosed that injection near the intake port with a spring loaded nozzle with the discharge phased with air flowing to the cylinder on the suction stroke, was desirable. Fuel consumption and power compared favorably with the best results obtained with the carburetor, under directly comparable conditions. Bench tests conducted with this injector indicated that the design was basically correct but that the performance needed to be materially improved. Bench tests with the nozzle indicated that it was unsatisfactory, mainly because the cut-off was not definite and fuel was delivered inconsistently throughout the entire engine cycle.

From July, 1928, to January, 1930, efforts were concentrated in developing fuel injectors of M. G. Chandler's basic design for multi-cylinder engines, built to Air Corps require-

ments by the Marvel Carburetor Co., as well as in developing a satisfactory discharge nozzle for injection into the induction system. During January of 1930, the Model E-185 injector and C-4 discharge nozzle, both of which were the result of the preceding bench test development work, were installed on the R-1340-7 engine for tests at the dynamometer. Testing with this engine was completed during October, 1930.

A full throttle endurance test at the torque stand of the (Pratt and Whitney Wasp) R-1340-7 engine equipped with a Model E-185 injector and C-4 discharge nozzle was started during November, 1930, and terminated after 53½ hours of satisfactory operation during December of 1930.

During 1931, Models E-220, E-250 and H-245 fuel injectors and several types of discharge nozzles became available for engine tests, as the result of development work accomplished on the bench concurrently with the above engine tests. Tests were made with this equipment installed on the following engines, during this year: Pratt and Whitney Wasps R-1340-15, R-1340-15 except 7.7 compression ratio pistons, R-1750-3 (Wright Cyclone) and V-1570-9 (Curtiss Conqueror). Also, during this year, an automatic load and automatic control for fuel injectors was designed and tested.

During December of 1931, a great deal of flight testing of the R-1340-15 engine, equipped with Model E-250 fuel injector and C-12 discharge nozzle, was accomplished with the Douglas BT-2A airplane, A. C. No. 30-222. These tests continued until September of 1932.

The R-1340-17 engine, equipped with Model E-250 fuel injector and C-13 discharge nozzle, was placed on the dynamometer during April of 1932, so that all necessary data for this installation in the P-12E (Boeing Pursuit) airplane could be obtained.

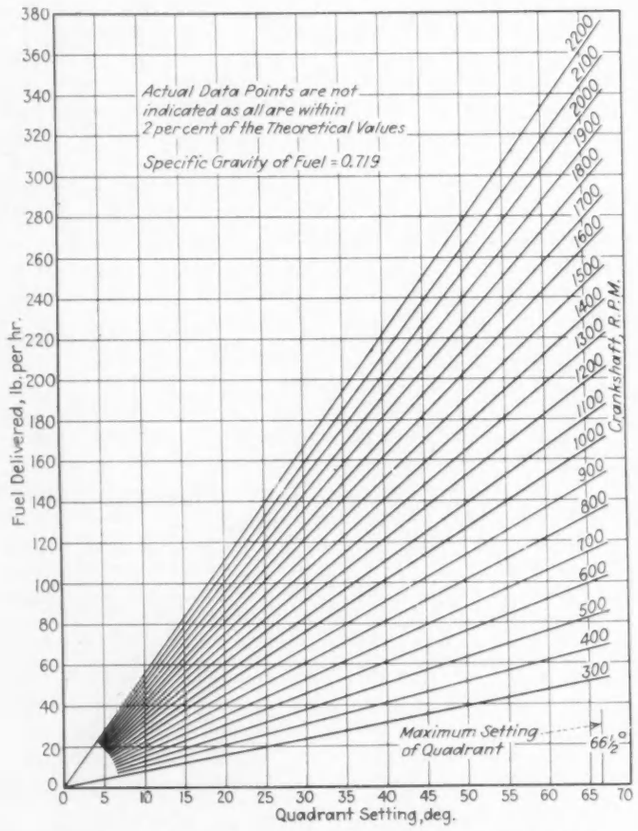

Actual Data Points are not indicated as all are within 2 per cent of the Theoretical Values
Specific Gravity of Fuel = 0.719
Fuel Delivered, lb. per hr.
Quadrant Setting, deg.
Crankshaft, R.P.M.
Maximum Setting of Quadrant
66½°

Fig. 1—Volumetric performance of Marvel E-220 fuel injector with 56 deg. exhaust cam, "C-12" discharge nozzle and ¼ in. copper feed tubes.

During November of 1932, the first flight tests with this engine and equipment were made as installed in P-12E airplane, A. C. No. 31-553. Numerous engine control units, control systems, fuel systems, etc., which are essentially different than for the carburetor, were tried in this airplane before all requirements regarding these items were satisfactorily accomplished. It might well be said that after the work at the bench, dynamometer and torque stands had been accomplished, the task of getting a satisfactory application in a service type airplane had just begun. The P-12E airplane, modified to take the R-1340-17 engine with the fuel injection system, was re-designated as the YP-12K airplane. During the first part of 1933, sufficient parts to convert a number of P-12E airplanes to YP-12K airplanes were designed and fabricated at this Division. The first YP-12K airplane for service test was released to Selfridge Field during September of 1933. By May of 1934, nine of these airplanes were furnished to Selfridge Field and two to Langley Field.

During April of 1933, work was undertaken by the Pratt and Whitney Aircraft Co. to design and build a new engine, except power section, especially for adapting the fuel injection device and its related equipment to meet the requirements of this Division. All work in this connection, together with development tests, performance tests and standard type test, was completed during August, 1934. Thirty-five of these engines with R-1340-27 power section, designated as the R-1340-33 engine, are now being fabricated for installation in P-26B airplanes.

During the first part of 1934, an Air Corps specification was prepared covering the adaptation of a fuel injection system to the V-1710 type engine. This consisted mainly of a manifolding study and was accomplished at the Allison Engineering Co., in an effort to meet the requirements of this specification.

Also, during the first part of this year, specifications for injectors suitable for 9-cylinder radial engines and 14-cylinder double row radial engines were prepared for the Eclipse Aviation Corp. Injectors made to meet the requirements of these specifications have been fabricated and are now undergoing development tests. A specification for an injector for installation on a 9-cylinder radial engine has been prepared for the United American Bosch Corp. This corporation is now working on designs and may at some subsequent date manufacture a device, in an effort to meet the requirements of this specification. All requirements for induction system fuel injection, as applied to present service engines and airplanes, are very definitely known at this Division at this time. Immediate efforts will be expended toward the development of an automatic load and altitude control for fuel injectors, as exhaustive studies of all types of mechanical control systems indicate that it is practically impossible with such systems to fulfill all the requirements for highly supercharged engines which are now being installed in service airplanes. Several sources of fuel injection systems are being developed in an effort to further the development of the system and reduce its cost. General specifications covering the requirements of the Air Corps for fuel injectors and for adapting fuel injectors and related equipment to aircraft engines have been prepared. General specifications covering discharge nozzles and a full automatic control are being prepared. It is hoped that many vendors will become interested in supplying items to meet these specifications so that development will proceed at a more rapid rate.

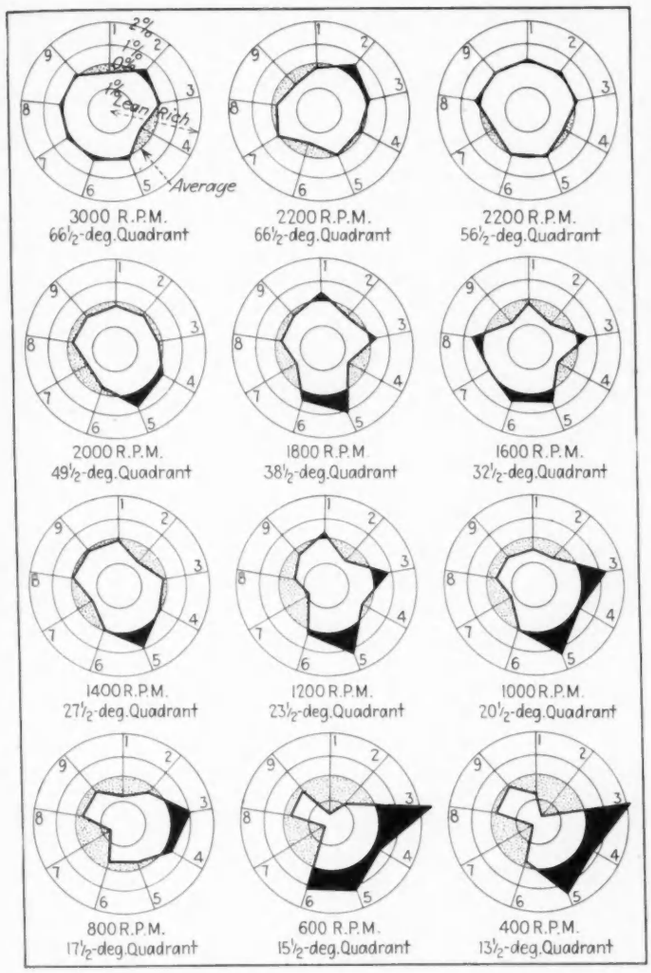


Fig. 2—Per cent variation from average in distribution for all outlets at various speeds and quadrant settings of Marvel E-220 fuel injector with 56 deg. exhaust cam, "C-12" discharge nozzle and ¼ in. copper feed tubes. (Speed noted is engine r.p.m.) Date of tests, December, 1931.

It is not intended to burden this paper with the many phases of development details, but, instead, to outline generally the results obtained with the developed material and to describe it. It should be appreciated, however, that many problems arose that seemed almost without solution and were solved only with the expenditure of a great deal of concentration and experimentation, as no precedent of experience along parallel lines existed. Had these problems and troubles not arisen, it is certain that our knowledge of fuel injection and its application at this date would be far less.

Fuel Injector Development and Bench Tests

After having finished the preliminary tests with the V-1150 and single cylinder engines, it was very evident that no injector was available which would come anywhere near meeting the requirements established. The most promising device was that invented by M. G. Chandler and used for the single cylinder tests. A 9-cylinder unit of this basic design was manufactured by the Marvel Carburetor Co. under the direction of Mr. Chandler, for development work by the Air Corps and was designated as the E-185. The E-220 injector, built during 1931 to take advantage of the development work obtained with the E-185, furnished performance which was within 2.5 per cent of the theoretical and withstood a 1000-hr. endurance test without change in performance. The volumetric performance of this injector at any rotative speed or stroke lever setting is shown by Fig. 1, the distribution characteristics by Fig. 2, the theoretical length of injection period by Fig. 3, the actual length of injection period by Fig. 4, and the instantaneous pressures in the fuel feed tube by Fig. 5.

It should be noted that the volumetric delivery is directly proportional to speed and to stroke lever setting and that the discharge terminates at the same angular position regardless of speed or stroke lever setting; also, that the period of delivery becomes shorter as the stroke is reduced. These characteristics are basically correct for the aircraft engine for induction system injection. Injectors built after the E-220 were refinements of it to accomplish better installations on engines, eliminate vapor lock at high altitude with volatile fuels, eliminate vapor lock due to parts being bathed with hot lubricating oil, reduce the force required to operate the control, and so forth. Fig. 6 and Fig. 7 show an up-to-date injector for a 9-cylinder radial engine, which is designated as Air Corps Type Q-2. This injector, including mounting bolts and gaskets, weighs 22 lb., has a maximum diameter of 7 in., is 7⅝ in. long, is rated at 568 lb. fuel per hr. with 0.719 specific gravity fuel at 1100 r.p.m. and requires approximately 0.35 hp. to drive it at rated conditions. The fuel outlets are in the mounting face and the injector is mounted with nine hollow combination mounting and fuel feed bolts. Drive is through a 3-in. Oldham coupling offset 1/16 in. to permit exchange of units without retiming. Lubrication is obtained from the engine system by a metered oil squirt through the center of the Oldham coupling. The oil is distributed inside the injector by the centrifugal force of the rotating parts and is returned to the engine by gravity. The injector is fitted with a spring loaded timing pin which drops into a notch, if it is depressed when the injector is in position to start discharging to number one cylinder, at full stroke. The strainer cap is fitted with a relief valve which regulates the pressure of the fuel supply to 3 lb. per sq. in. A fixed element screen of 0.0025 in. free opening is fitted at one end of the injector and

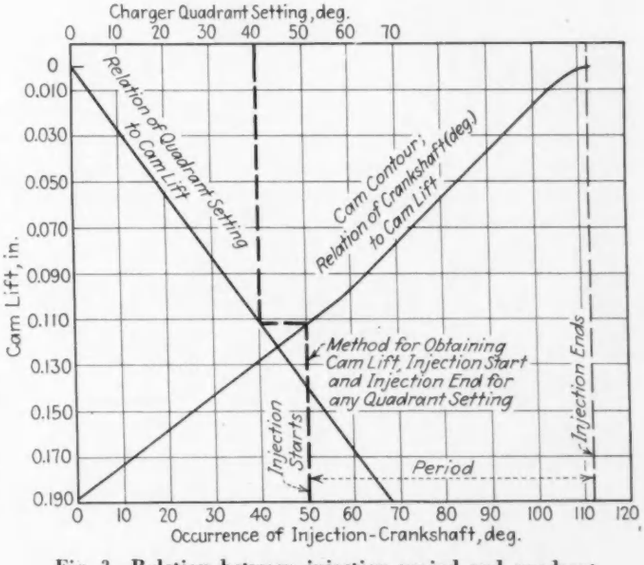


Fig. 3—Relation between injection period and quadrant setting of Marvel E-220 fuel injector with 56 deg. exhaust cam "C-12" discharge nozzle and ¼ in. copper feed tubes.

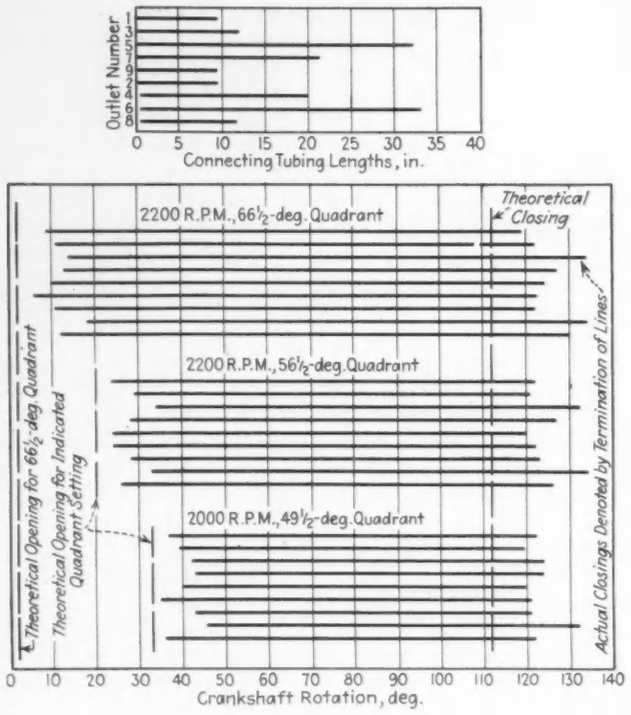


Fig. 4A

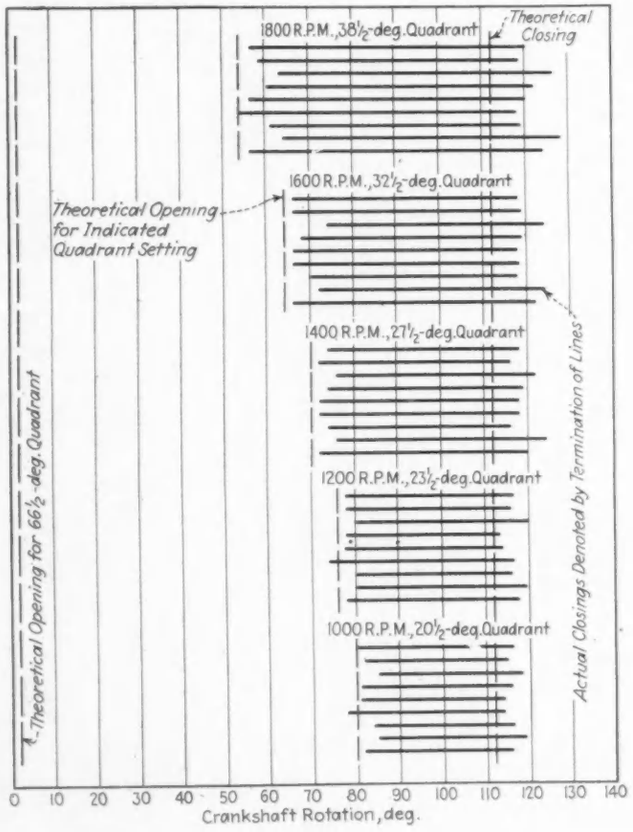

1800 R.P.M., 38½-deg. Quadrant
Theoretical Closing
1600 R.P.M., 32½-deg. Quadrant
Theoretical Opening for Indicated Quadrant Setting
1400 R.P.M., 27½-deg. Quadrant
1200 R.P.M., 23½-deg. Quadrant
1000 R.P.M., 20½-deg. Quadrant
Theoretical Opening for 66½-deg. Quadrant
Actual Closings Denoted by Termination of Lines
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140
Crankshaft Rotation, deg.

Fig. 4B

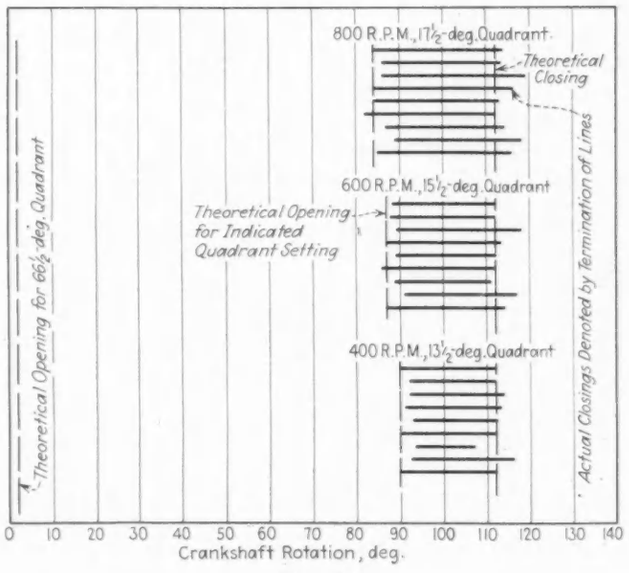

800 R.P.M., 17½-deg. Quadrant
Theoretical Closing
600 R.P.M., 15½-deg. Quadrant
Theoretical Opening for Indicated Quadrant Setting
400 R.P.M., 13½-deg. Quadrant
Theoretical Opening for 66½-deg. Quadrant
Actual Closings Denoted by Termination of Lines
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140
Crankshaft Rotation, deg.

Fig. 4C

Figs. 4A, 4B and 4C—Actual as compared to theoretical period as determined by oscilloscope observations of discharge nozzle at various speed and quadrant settings of Marvel E-220 fuel injector with 56 deg. exhaust cam, "C-12" discharge nozzle ¼ in. copper feed tubes. Date of tests, December, 1931.

is retained by a snap ring. Removal of the screen is accomplished by removing the strainer cap which is held by one screw and removing the snap ring.

Maintenance of Injector

Throughout the entire development period, thought has been given to installing and timing, to make possible the exchange of units by unskilled mechanics, and as a result the up-to-date injector is fool-proof, as far as handling in the service is concerned. A redesign of present radial engine rear and center sections was necessary, however, to achieve this. To install the injector on a redesigned engine requires no more skill than is necessary in setting the engine for a given position of the engine cycle and bolting the injector on. Once installed on the engine, it is difficult deliberately to tinker or cause interference with the injector operation. The lever for stroke adjustment can be operated through any desired arc of a complete circle and is provided with an eccentric adjustment which permits setting of the lever at any exact position desired.

The injector design has been arranged so that a minimum of tools is required for servicing and assembling. The replacement of parts is very easily accomplished. Since injectors must be capable of 1000 hr. of operation without replacement or change in performance, it is expected that very few injectors will ever reach servicing depots in case of a national emergency.

Requirements—Injectors

The requirements of the Air Corps for injectors are completely outlined in Air Corps Specification No. 28168. This specification is available to those who may care to attempt to construct an injector for a military aircraft engine.

Development of Discharge Nozzles

While the injector was developed by bench studies, this was not possible in the case of the discharge nozzle, since requirements for nozzles had not been definitely established and the conditions under which the nozzle operated were not

definitely known. Tests at the dynamometer with R-1340 type engines fitted with Pyrex intake pipes and many types of nozzles furnished the necessary information for establishing requirements for a satisfactory discharge nozzle. It became very evident, from observations of the performance of the various nozzles, that the nozzle must be dried immediately after the injection pressure surge subsides and should remain so until the beginning of the next succeeding surge. Any pocket or projection between the nozzle seat and the point at which fuel leaves the nozzle assembly will increase the time required to vaporize the fuel, lengthen the period to dry the nozzle and reduce the chances for complete vaporization in the intake pipe during the suction stroke. The tendency for partially vaporized fuel to condense to a liquid immediately upon hitting a projection must be fully realized and provisions to reduce this to a minimum are essential. With a good nozzle arranged properly in the induction system, it is possible to have the charge, during each suction stroke, completely vaporized before it enters the combustion chamber.

The discharge nozzle shown by Fig. 8 is the most satisfactory of any developed to date, and is the fourteenth in the order of development in its particular series, two other series having been developed and discarded. With this nozzle, fuel discharges uniformly around the circumference of the seat in a flat sheaf. The heavy or penetrating part of the sheaf upon striking the baffle ring is formed into a conical sheaf and is deflected against the air current flowing to the cylinder. The velocity of the air is sufficient to bend immediately the sheaf around approximately 120 deg. during which time a great deal of vaporization and intimate mixing is accomplished. The fine mist present around the seat and baffle ring is swept towards the cylinder and disappears from sight after having moved 3 to 4 in., because of being vaporized. All vaporization, including that of the heavy part of the spray, is practically completed by the time the charged air is 7 in. downstream from the leading edge of the nozzle. A fixed element type fuel screen with 0.001 in. free opening is fitted to the nozzle assembly. Even with this precaution against foreign material, erosion of the seat and diaphragm will occur after a few hours of operation unless these are made of selected materials. A common stainless steel cyanided was found to be satisfactory for the seat while tantalum, specially heat treated, is required for the seating diaphragm.

Nozzles employing spring loaded spindles or valves were found to be unsatisfactory because the natural period of the spring and related assembly was such that in parts of the operating range this period coincided with the pulsations in the fuel feed tube and caused fuel to discharge, out of phase with respect to the air-stream moving to the cylinder. Also, no design could be obtained which would keep fuel from pocketing or collecting on the nozzle body.

Further discussion of injector and discharge nozzle is entered into later during the discussion of results obtained with various engines.

At the completion of preliminary engine tests, it was known that a system could be devised which would furnish satisfactory performance during tactical maneuvers and which would equal the carburetor performance, but the project was carried farther because it was evident that the fuel consumption could be decreased and power increased. As the development of the injection system has progressed it has become more and more evident that a perfect carburetor could never cause engine performance which would equal that obtained with a good injection system and related equipment.

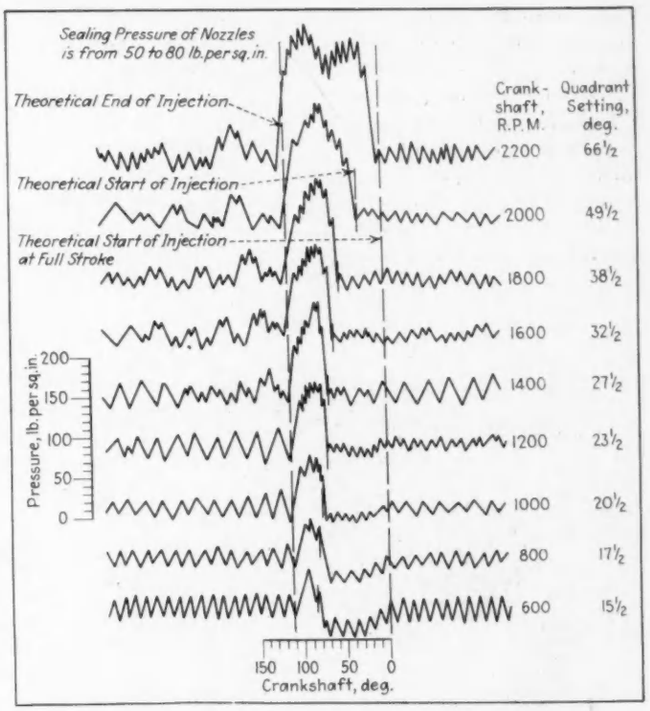


Fig. 5—Instantaneous pressures in connecting fuel feed tube, 36 in. long, of Marvel E-220 fuel injector with ¼ in. diameter connecting tube and 175-200 lb. per sq. in. nozzle tension.

Application of Injection Systems

Probably the most important consideration in making a good application of induction system fuel injection to the Otto cycle engine is that of phasing the fuel discharge with the suction impulse. To accomplish this, it is necessary to know the instantaneous velocities during the entire suction stroke for all speeds and loads in the complete range of operation. It was thought that the instantaneous pressure difference between the intake port and combustion chamber, together with the instantaneous values of air density in the induction system, would permit calculation of the instantaneous velocities, if a proper coefficient of discharge for the system were known. Accordingly, this information was obtained by use of sampling valve indicators, data being taken at each 20 deg. of crankshaft movement. The computed velocities could not be relied upon as being accurate because the pressure surges in the induction system were not uniform between cycles and, thus, it was not possible to know if the pressure differences recorded were actually present or if it was due to the occurrence of a pressure surge. Typical data for one operating condition of load and speed are shown by Fig. 9.

A flat-disc, spring-loaded vane, of the least practical inertia was calibrated and installed in a Pyrex manifold at the location selected for the discharge nozzle. The discharge nozzle was installed in the intake port for these tests. The deflection of the disc at each 20 deg. of crankshaft movement during the suction stroke was observed with a rotoscope driven through phase gearing from the engine. From calibration curves of the vane, it was possible to read directly the true velocity by noting the deflection and air density. The density was computed for each 20 deg. from the pressure and temperature, the pressure being an instantaneous value while the

temperature was, of course, an average. The information thus obtained indicated that the maximum velocities were of the order of 260 ft. per sec. Computations showed that the slight inertia of the vane was sufficient to cause errors in the displacement of the velocity values with respect to crankshaft angularity which could not be definitely determined, so this attempt was dropped. However, a great deal was learned regarding the general direction of the air currents during the cycle. It was very conclusively proved that under certain conditions, air will flow into the cylinder through the exhaust valve and out of the cylinder through the intake valve and enter the supercharger.

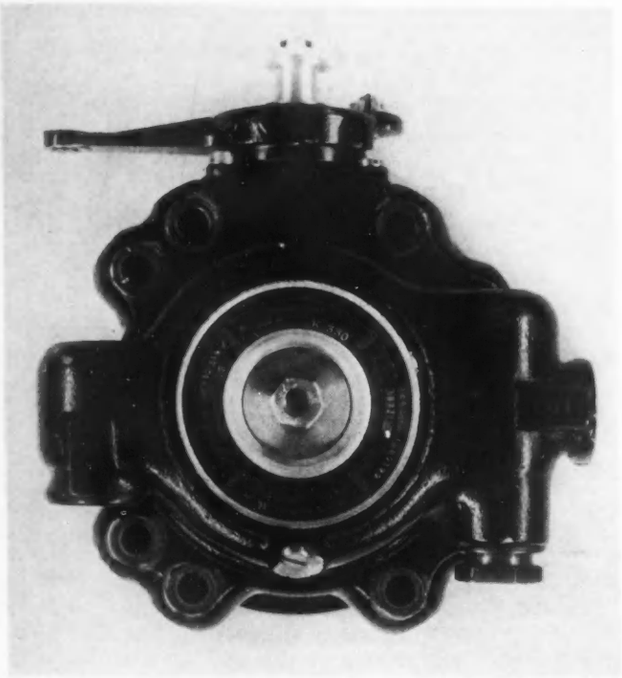


Fig. 6

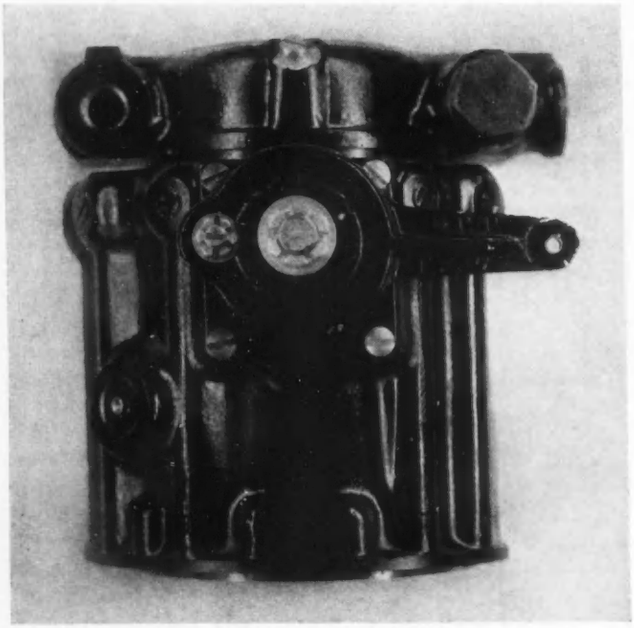


Fig. 7

Figs. 6 and 7—Air Corps, Type Q-2 fuel injector, used with up-to-date nine cylinder radial engines.

A pitot static tube was next assembled to a special valve body for installation of a sampling valve indicator, so that the whole assembly could be clamped direct to the intake pipe. The static and impact tubes were located in the intake pipe at the place selected for the discharge nozzle. Despite all efforts to reduce tube lengths and volume in the system to a minimum and cause exact synchronism of the readings of impact tube and static tube values, the data were not reliable because of the erratic effects of pressure surges in the induction system.

The final attempt was successful and was accomplished by installing a special nozzle with a 90 deg. included conical angle of spray (in still air), together with a scale for indicating angularity of the spray sheaf. The angularity of the sheaf was observed through a rotoscope, which was driven through phase gearing from the engine, observations being made at 6 deg. intervals during the suction stroke. Care was taken to advance the injector timing for each observation so that the spray would be observed at the same intensity each time. After covering the complete range of loads and speeds, the cylinder with intake pipe and nozzle was removed from the engine and installed in the carburetor test chamber for calibration. The exact procedure accomplished at the dynamometer was repeated, maintaining the same conditions of density, etc., but in this case the air consumption was regulated to produce the spray angles obtained on the engine. By noting the values of air consumption to produce the observed spray angles, it was possible to compute the true velocity, as the area of the pipe was known, as well as the density of the air.

These tests were of extreme value in establishing, by actual vision, what took place in the induction system and correlating that with data on the phenomenon which caused the action. It is not practical to attempt to show graphically in this paper the values of instantaneous velocity during the suction stroke over the range of speeds and loads covered, as a general statement will suffice. Operating with throttle stop horsepower at 2120 r.p.m. the velocity in the intake pipes of the R-1340-17 engine is zero at 32 deg. ATC, reaches a value of approximately 290 ft. per sec. at 74 deg. ATC, and maintains this value until 158 deg. ATC, after this part of the cycle the velocity decreases, reaching a zero value at 212 deg. ATC. Idling at 400 r.p.m., with the throttle closed, the velocity is zero at 40 deg. ATC, reaches a value of approximately 130 ft. per sec. at 90 deg. ATC, and maintains this value until 130 deg. ATC, after this part of the cycle the velocity decreases reaching a zero value at 180 deg. ATC. For speeds and loads, obtainable with a propeller, within these extreme conditions, the velocities can be determined approximately by proportion.

Location of Nozzle

After the instantaneous velocities were known, it was possible to pick a location for the discharge nozzle which satisfied the greatest number of requirements and to study and develop the nozzle in the carburetor test chamber. It was found that in general the point of discharge should not be closer than 7 in. to the intake port and that the volume contained in the induction system from the point of discharge to the combustion chamber should be less than the least volume taken in on any suction stroke. The "least volume" is considered to be approximately 35 per cent of the cylinder displacement for present radial type engines with large valve overlaps. Fig. 10

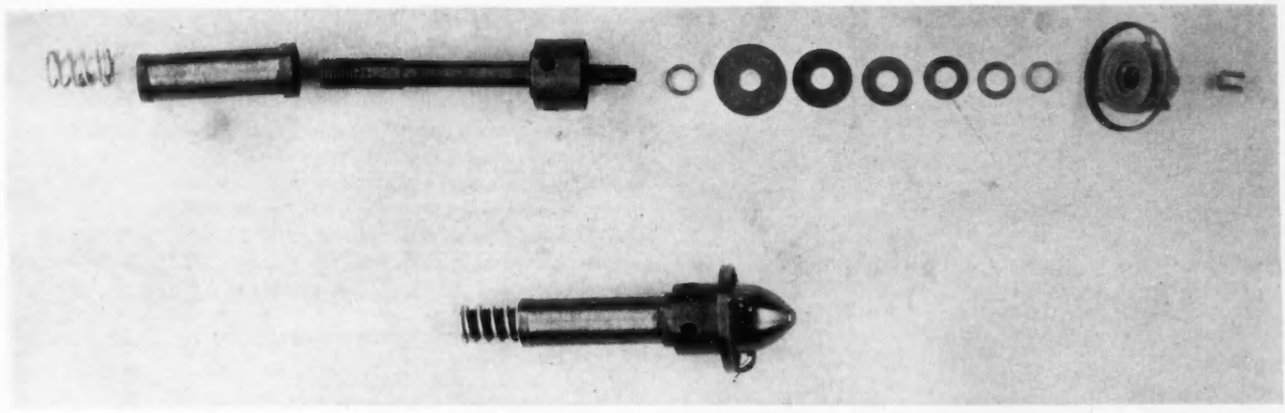


Fig. 8—Discharge nozzle, Air Corps type C-14. The most satisfactory type developed to date.

illustrates the location found most satisfactory for the discharge nozzle used with the R-1340 type engine.

Injection Timing

By conducting injection timing calibrations and mixture control calibrations with many injection timings, it was found that only certain parts of the suction stroke were good for the development of maximum power and obtaining good economy. Data for an injection timing calibration are shown by Fig. 11, for the R-1340-15 engine. The fuel-air ratio was maintained at a constant value for the calibration. It will be noted that the horsepower peaks at the earliest part of the stroke at which the combustibles in the exhaust become a minimum, which is 80 deg. ATC of the suction stroke. It is believed that the peak is reached with this timing, mainly, because the charge becomes well vaporized before it enters the combustion chamber and because it assumes some particular advantageous degree of stratification and that these conditions make for more complete and efficient combustion than obtainable with other timings. The duration of the injection period has a slight effect on the power developed and a marked effect on the economy. It has been found that lengthening the period from 80 deg. of crankshaft displacement to 110 deg., at full throttle, full stroke, increased the power slightly and improved the specific fuel consumption considerably. It has also been found advantageous to decrease the duration of the period as the power is throttled and speed reduced on propeller load. To keep the fuel discharge well phased with the air moving to the cylinder during the suction stroke, the periods should vary in the general order indicated by Fig. 4. The period should be shortened by starting injection later in the cycle and keeping the end of the period constant.

Referring again to Fig. 11, it will be seen that the temperature of the charged air entering the intake port decreases until 115 deg. ATC and then increases to a rather high value. This indicates, in general, the amount of vaporization which has been accomplished between the nozzle and the intake port and shows that with late injection, when the fuel is not properly phased with the air, a relatively small amount of vaporization is accomplished. Also, it can be noted that the amount of combustibles in the exhaust increases with this decrease in vaporization. With late injection, fuel gets back into the supercharger and the effect is noted on the temperature recorded at the supercharger diffuser.

Timing and duration of injection have a direct bearing on the distribution of the fuel charge to the proper cylinders. From the standpoint of distribution of fuel, it is desirable to inject as soon after the air starts to flow to the cylinder as the air can support and carry the fuel, and to terminate the injection in sufficient time so that all the fuel will enter the cylinder before the intake valve closes. This will mean that the entire induction system branch to each cylinder will be dry before and after each suction stroke and that the fuel charge has gone only to the cylinder for which it was intended. Fortunately this can be accomplished without any sacrifice in power or economy. It might even be said, in

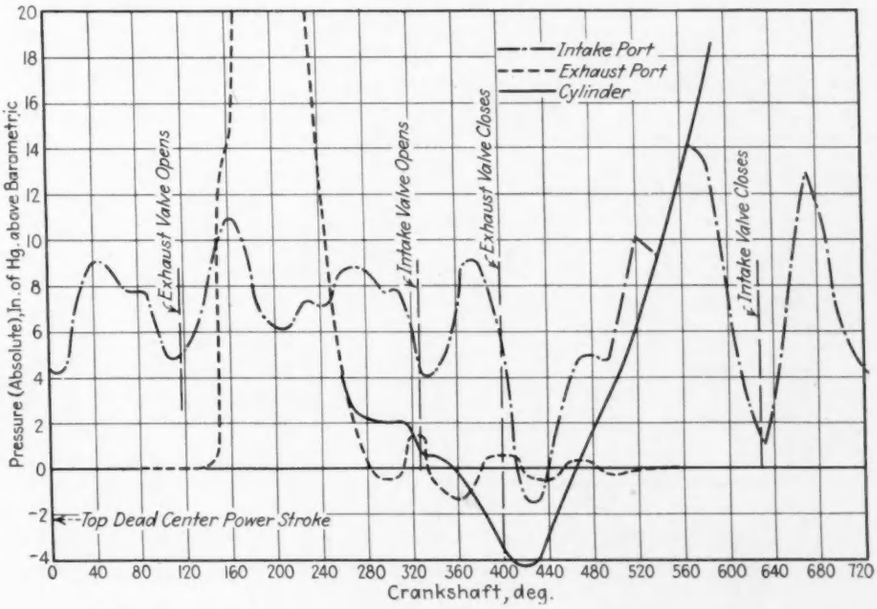


Fig. 9—Intake port, cylinder and exhaust port pressures at 2120 r.p.m. flight propeller load. (R-1340-17 engine; A. C. No. 32-167, E-220-4 injector; true barometer, 29.19 in. of mercury; intake air temperature, 71 deg. fahr.) Date of test, November 12, 1932.

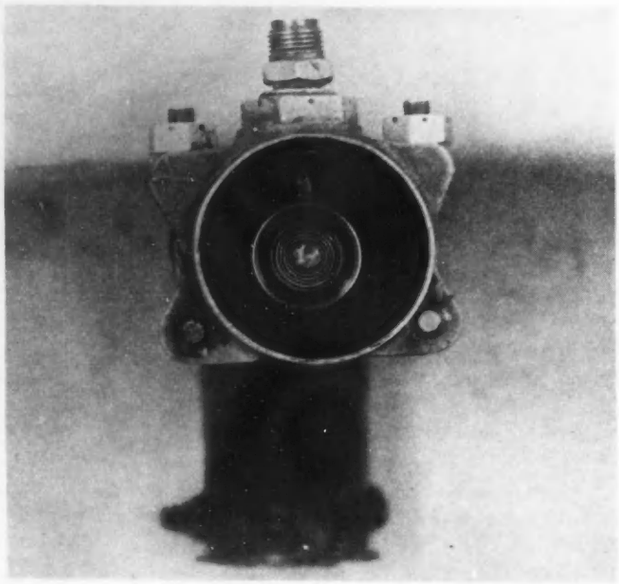


Fig. 10—Location found most satisfactory for discharge nozzle used with R-1340 type engine

general, that if this is not accomplished, the power and economy will not be as good as could be obtained by accomplishing these conditions.

Economy and Efficiency at Dynamometer

Data for a typical mixture control calibration are shown by Fig. 12. It should be noted that the power developed is practically constant over a wide range of mixture strengths. This, together with the slope of the horsepower curve with lean mixtures, is thought to be indicative of excellent distribution, good stratification and good combustion. The indicated specific fuel consumption is 0.378 lb. per hp-hr. which

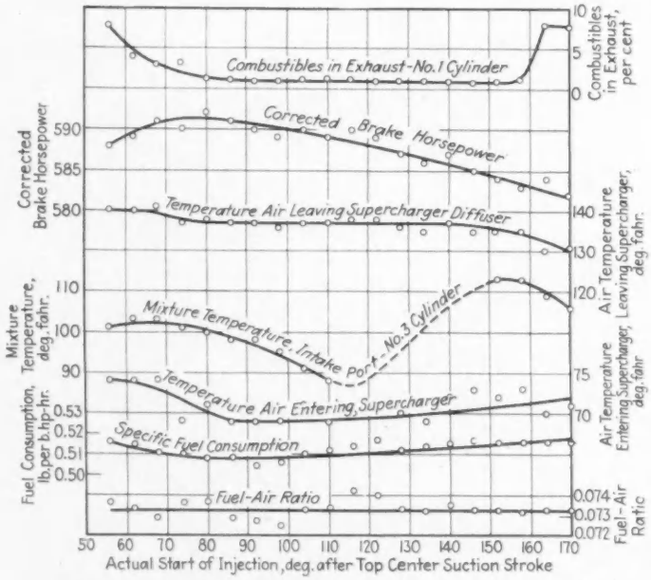

Combustibles in Exhaust-No.1 Cylinder
Corrected Brake Horsepower
Temperature Air Leaving Supercharger Diffuser
Mixture Temperature-Intake Port-No.3 Cylinder
Temperature Air Entering Supercharger
Specific Fuel Consumption
Fuel-Air Ratio
Corrected Brake Horsepower
Combustibles in Exhaust, per cent
Air Temperature Leaving Supercharger, deg. fahr.
Mixture Temperature, deg. fahr.
Air Temperature Entering Supercharger, deg. fahr.
Fuel Consumption, lb. per b.hp-hr.
Fuel-Air Ratio
Actual Start of Injection, deg. after Top Center Suction Stroke

Fig. 11—Results of injection timing investigation at 2000 r.p.m. full throttle. (R-1340-15 engine; A. C. No. 31-89; Marvel E-330 injector; "C-6" discharge nozzle; true barometer 28.88 in. of mercury; relative humidity, 56 per cent; air blast, 60 deg. fahr.; air consumption held between 3910 and 3950 lb. per hr.) Date of test, March 3, 1931.

corresponds to a thermal efficiency of 35.5 per cent. This efficiency is 69.5 per cent of the theoretically perfect, or air cycle efficiency of 51 per cent for the R-1340-17 engine. The thermal efficiency based on b. hp. is 31.9 per cent. If fuel can be obtained, which will permit this engine to be operated at full throttle, at ground level, it is believed that a still closer approach to the theoretical will be obtained. There are many other lines of approach for increasing the efficiency of the cycle, but these can well be left for future investigation.

Mixture strength requirements and specific fuel consumptions for the R-1340-17 engine are shown by Fig. 13. These

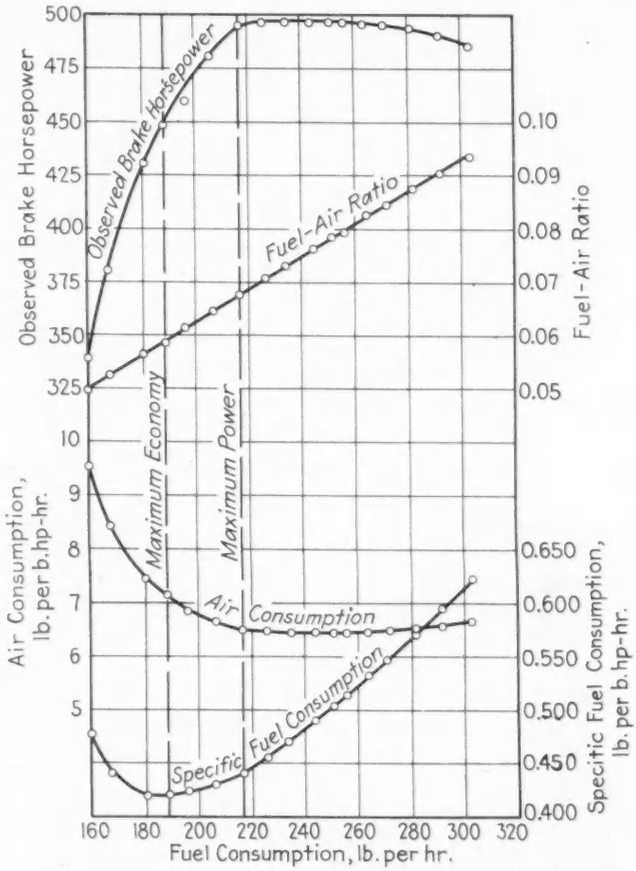


Fig. 12—Data for typical mixture control calibration. (Flight propeller load, 2000 r.p.m.; R-1340-17 engine; A. C. 32-142; Marvel E-250 injector; MCP-49-505-X discharge nozzle; true barometer, 29.31 in. of mercury; air at throttle 73-75 deg. fahr.; relative humidity, 27 per cent; air blast temperature, 81-86 deg. fahr.; actual air consumption held between 3231 and 3202 lb. per hr.) Date of test, April 28, 1932.

have been obtained from mixture control calibrations similar to that shown by Fig. 12 and cover all the range of operation, except full throttle and idling.

Load Compensation

A load compensation calibration for the R-1340-17 engine, with control linkage, as used for this engine in the YP-12K airplanes, is shown by Fig. 14. The data of this curve are self-explanatory and indicate the desirability of employing an injector with the characteristics discussed earlier in this paper.

Controls and Linkage

Fig. 15 furnishes data for flight propeller load obtained with the R-1340-17 engine. The mixture strengths are obtained by

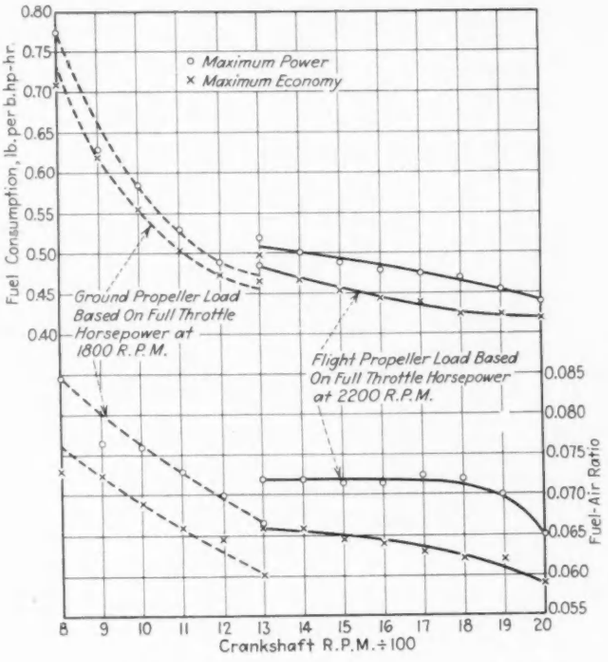

Maximum Power
Maximum Economy
Ground Propeller Load Based On Full Throttle Horsepower at 1800 R.P.M.
Flight Propeller Load Based On Full Throttle Horsepower at 2200 R.P.M.
Fuel Consumption, lb. per b.hp-hr.
Fuel-Air Ratio
Crankshaft R.P.M.÷100

Fig. 13—Mixture strength requirements and specific fuel consumptions for R-1340-17 engine. (A. C. No. 32-142; Marvel E-250 injector; and MCP-49-505-X discharge nozzle; air at throttle—maximum 82 deg. fahr., minimum 66 deg. fahr.; relative humidity—maximum 45 per cent, minimum 25 per cent; air blast—maximum 86 deg. fahr., minimum 45 deg. fahr.) Date of tests, April 1, 1932 to May 3, 1932, inclusive.

correlated movement of the throttle valve and injector control lever through a cam and related control linkage. These mixture strengths are based on the requirements shown by Fig. 13, with sufficient enrichening to assure satisfactory performance and adequate protection to the engine. The necessity for a control linkage cam can be realized from inspection of throttle angularity versus injector control angularity. Thirteen airplanes have been in service for a considerable length of time with these engines and are giving good service.

Power Performance

A considerable gain in performance has been obtained where the conventional carburetor has been replaced with the fuel injection system. This gain is attributed almost entirely to an increase in air consumption brought about by eliminating the pressure drop through the air heater, carburetor and hot spot. It is not possible to state a general figure for the gain because the gain is dependent on how good the standard carburetor, air heater and hot spot designs are. The least gain made in any installation to date has been 8 per cent and the greatest 15 per cent. A slight gain in power is always obtained which can be attributed to more complete combustion, which is probably accounted for by the difference in stratification obtained with the fuel injection system, and better vaporization of the charge. If the supercharger is redesigned to take advantage of the fact that it has to handle air only, a still further gain in performance can be expected.

The increase in performance obtained by installing the fuel injection system on the R-1340-17 engine is reflected in the airplane performance, as shown by Fig. 16. In this particular case the same engine and airplane were used for tests with carburetor and injection system, and the results shown are directly comparable and show the true gain. The performance of this airplane during the execution of tactical maneuvers and inverted flight was excellent.

Engine Design

It was realized as early as 1930 that it would be necessary completely to redesign the rear and center sections of radial engines if the optimum results were to be obtained in regard to performance, serviceability and installation. During 1933, the requirements of the Air Corps, in regard to adaptation of fuel injection and related equipment, were made known to aircraft engine vendors and negotiations were made with the Pratt and Whitney Aircraft Co. for designing, constructing and testing a new rear section for the R-1340 type engine. Of the large number of designs made, that which is shown by Figs. 17, 18 and 19 was finally approved. This design has cast-in fuel feed tubes and cast-in nozzle adapters which eliminate fuel feed tube failures, throttle bores machined in the rear section, a pad machined on the casting for mounting the control linkage, a mounting pad for the injector with cast-in stainless steel inserts, provision for driving the injector, lubricating the injector and many other special features. The passages in the supercharger were designed with exceptionally large volume and a considerable gain in supercharger efficiency was realized which could not have been accomplished if a carburetor had been employed. Attention is invited to the discharge nozzle mounting shown by Fig. 17, the general compact arrangement of the rear section and accessories shown

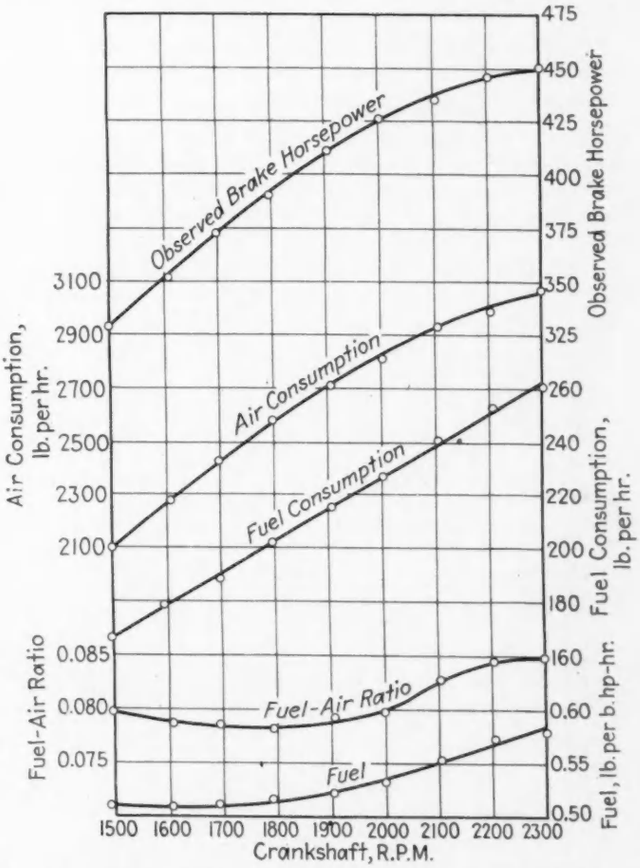


Fig. 14—Load Compensation Calibration with Controls Locked in Position for 1900 R.P.M. on Flight Load. (R-1340-17 engine; A. C. No. 32-142; Marvel E-250 injector; and MCP-49-505-X discharge nozzle; true barometer, 28.71 in. of mercury; air at throttle, 64-68 deg. fahr.; relative humidity, 46 per cent; air blast temperature, 64 deg. fahr.) Date of test, Feb. 7, 1932.

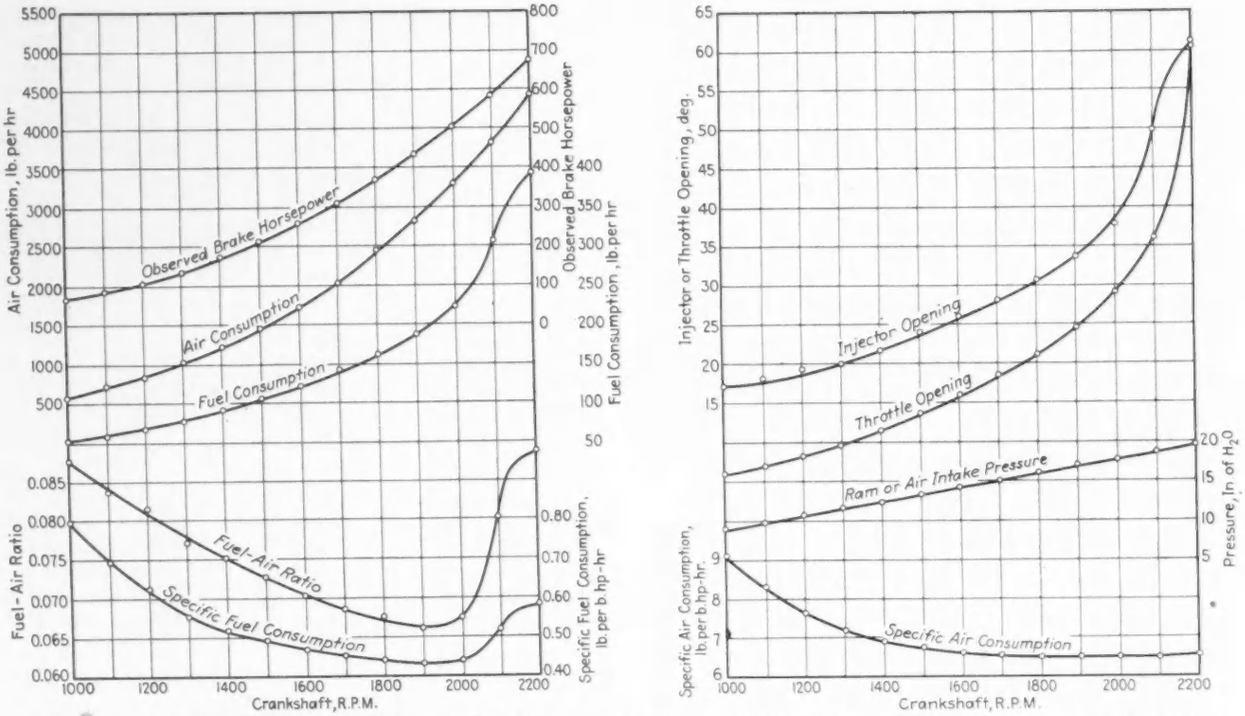


Fig. 15A and 15B—Flight propeller load, R-1340-17 engine. (A. C. 32-142; Marvel E-250 injector and MCP-49-505-X discharge nozzles; specific gravity of fuel, 0.700.) Date of tests April 1 to May 3, 1932, inclusive.

Data shown represent the original data corrected to barometer of 29.92 in. of mercury, ram indicated and throttle air temperature 60 deg. fahr. to obtain injector and air throttle settings obtained by use of the cam and linkage shown on installation DWG X 33G6342. Air intake pressures are those for flight at sea level.

by Fig. 18, and the control linkage shown by Fig. 19. The design was arranged so that with all accessories installed it is possible to install the engine in a standard mounting ring without removing any parts or accessories. Also, this complete rear section can be used with any Pratt and Whitney single row radial engine fabricated to date with the exception of the R-985 type. With this rear section and power section of the R-1340-27 engine, 825 b. hp. has been developed at 2200 r.p.m. The power developed with the R-1340-27 engine, which has the same impeller tip speed, but is equipped with a carburetor, is 730 b. hp. at 2200 r.p.m. This represents a gain of 13 per cent in power which can be directly attributed to the rear section and fuel injection system. It is interesting to note that 825 b. hp. at 2200 r.p.m. for the R-1340 type engine corresponds to a b.m.e.p. of 221 lb. per sq. in. The maximum brake horsepower taken from this engine in service is 600. Thirty-five of these engines are being fabricated for installation in P-26B airplanes.

Application Requirements

All engine vendors supplying engines to the Air Corps are now designing their engines to accomplish an application of the fuel injection system and related equipment similar to that accomplished by the Pratt and Whitney Aircraft Co. The requirements of the Air Corps for the application and adaptation are outlined in Air Corps Specification 28169.

It has been tentatively planned that all engines procured after July 1, 1935, for single-engined airplanes, will be equipped with fuel injection accomplished to meet the requirements of Specification 28169.

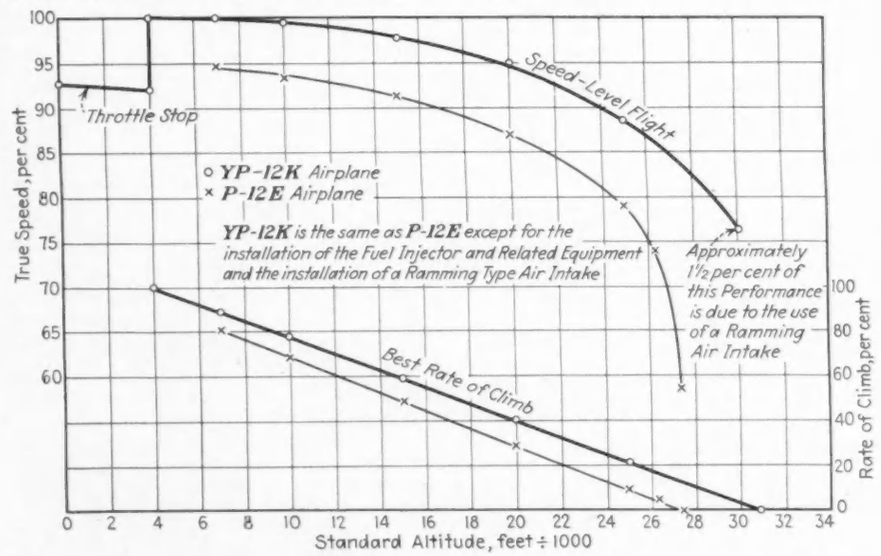

True Speed, per cent
Throttle Stop
Speed-Level Flight
o YP-12K Airplane
× P-12E Airplane
YP-12K is the same as P-12E except for the installation of the Fuel Injector and Related Equipment and the installation of a Ramming Type Air Intake
Approximately 1½ per cent of this Performance is due to the use of a Ramming Air Intake
Best Rate of Climb
Rate of Climb, per cent
Standard Altitude, feet ÷ 1000

Fig. 16—Comparison of P-12E and YP-12K Airplane Performance. (R-1340-17 engine used in both airplanes)

Airplane Installation

Installation of a fuel injection equipped engine in an airplane with the control system arranged for a carburetor equipped engine requires reworking the entire control system and the installation of a special engine control unit. The control system is entirely different than for the carburetor, inasmuch as the control linkages from the engine control unit

in the cockpit for the fuel injector and for the air throttle are required to move parallel at all times when the position of the throttle is changed. To obtain a reduction in fuel consumption to compensate for decrease in power with increase in altitude, it is necessary to arrange for movement of the control system to the injector without moving the control system to the air throttle. This requires an engine control unit which permits differential movement at will or positive movement of both control systems together in unison. An engine control unit, developed by the Air Corps to accomplish the desired results, is shown by Fig. 20, as installed in the cockpit of the YP-12K type airplane. The cross bar on the control handle is latched in the position shown and is left in this position until it is necessary to lean the mixture at altitude or enrich the mixture for starting and warm-up. To move the cross bar from its latched position, it is necessary to depress the latch button and then rotate the bar. The movement for leaning or enrichening the mixture is indicated by Fig. 20. Fore and aft movement of the entire control handle, regardless of the setting of the cross bar, moves the injector and air throttle linkage a like amount. With this type of control, the pilot has complete control over the throttle and mixture with his left hand. It is necessary for the control systems throughout to be mounted on ball bearings in order that no backlash will be present.

The mechanical control system, as described, has several disadvantages which are more or less inherent in any system conceived to date. This chief disadvantage is the complication of the installation and the fact that it is very easy to tinker with it and throw it out of adjustment. It has been realized for quite a few years that a fuel automatic control will have to be employed for controlling the injector. To date three automatic controls have been made and tested but none have proven to be basically correct. Sufficient information is available for the designing of a fourth control which is known to be basically correct and which should be very reliable, as it is simple and can be constructed ruggedly. The development of an automatic control for fuel injectors, used with the aircraft engine, has been intricate due to the fact that these engines are highly supercharged and are operated in air densities which vary through wide limits.

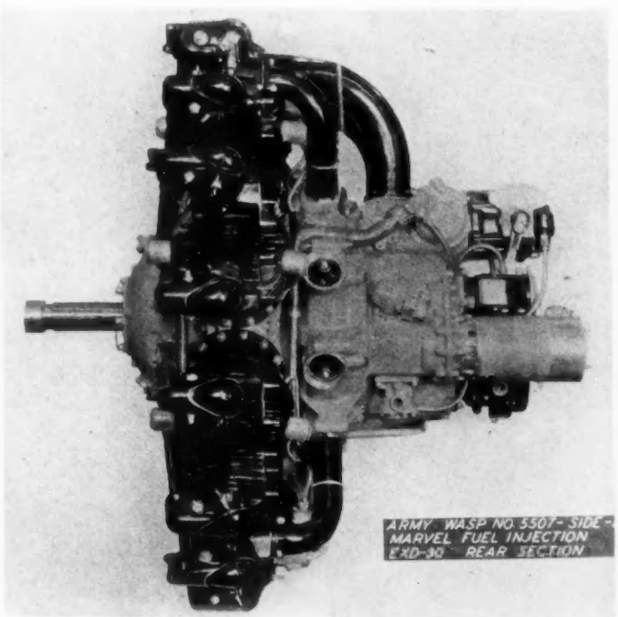


Fig. 17—Discharge nozzle mounting in Pratt & Whitney R-1340-33 engine.

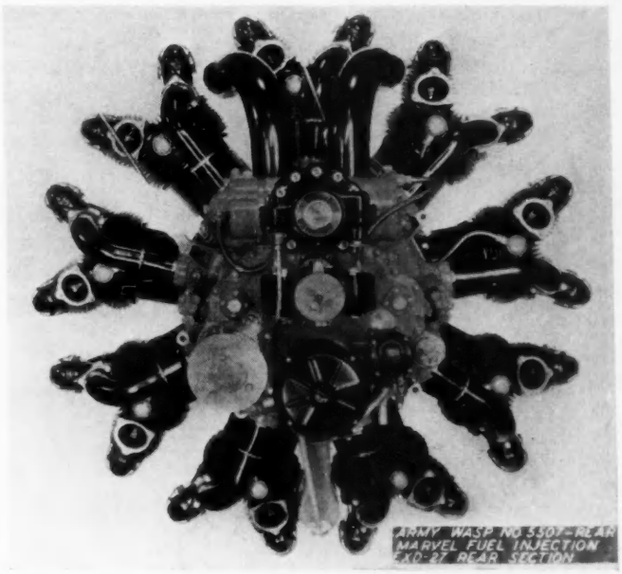


Fig. 18—General compact arrangement of the rear section and accessories of the Pratt & Whitney R-1340-33 engine.

The fuel system employed in an airplane in which a fuel injection engine is installed must be different from that for an installation with an engine equipped with a carburetor because vapor in the fuel must be vented before it reaches the injector and the excess amount of fuel handled by the transfer pump must be returned to the tank from which the transfer pump is drawing. Also, any vapor formed in the fuel at the injector must be vented through the fuel system. The system found best to date includes two fuel cocks of standard design synchronized in movement by a small gear box and arranged so that when the pilot turns the fuel cock valve he moves both fuel cocks, and the excess fuel from the transfer pump is returned to the tank from which it was drawn. The return lines are installed so as to allow vapor which has been formed in the system to be swept back to the supply tank and vented there to the atmosphere. The pressure relief valve is installed in the injector in all cases. A fuel pressure of 3 lb. per sq. in., which is standard for carburetors used by the Air Corps, has been retained as a standard for fuel injectors.

Installations in airplanes of engines, such as the R-1340-33, which is shown by Figs. 17, 18 and 19, and others which have been designed to meet the requirements of Air Corps Specification 28169, will be accomplished much easier than engines equipped with carburetors.

An outstanding advantage of the fuel injection system is the elimination of the ice formation in the induction system. This eliminates the necessity for air pre-heaters, jacketed induction systems and hot spots. The elimination of these items makes for a much easier installation in the airplane, reduces the installed weight of the engine and leaves more room for servicing. Elimination of pre-heat is quite an advantage because the power does not have to be reduced when operating in weather conditions which are favorable for the formation of ice.

When an automatic control becomes available, this will cause a simplification of the control system. The more compact arrangement of engine accessories, and better grouping,

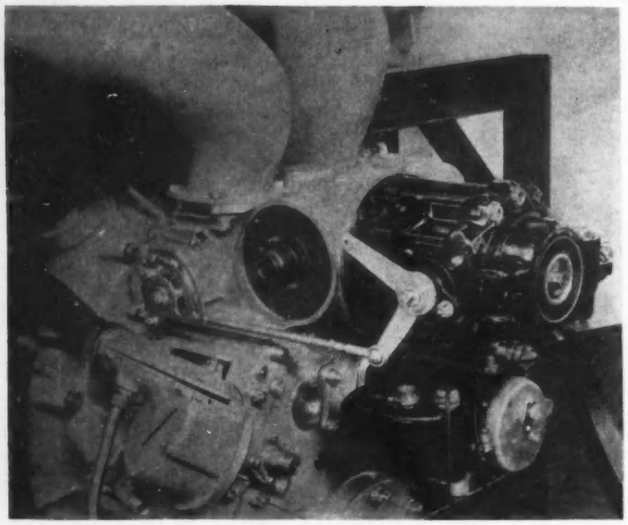


Fig. 19—Injector and throttle control linkage of Pratt & Whitney R-1340-33 engine.

will reduce installation problems. Also, the accessories will be more easily serviced due to improved clearances and less interference points.

While the fuel injection system, as applied and used to date by the Air Corps, has resulted in the realization of improvement in maneuverability, power, economy, starting, elimination of ice formation hazard, etc., there is still a great deal that can be accomplished which cannot be accomplished with a carburetor installation. It might be said that the surface of the reservoir of possibilities has just been touched. One thing in this connection is the possibility of using a bi-fuel system. Tests have already been made with alcohol and water, also, gasoline and water, in an effort to obtain greater performance than can be obtained with present service fuels. The results of these tests have been most encouraging. It has been found that with an addition of as little as 6 per cent of water (by weight) to gasoline, a considerable increase in power can be obtained before reaching the limits of the fuel in regard to detonation and pre-ignition. Also, it has been found that as much as 36 per cent of water can be injected with gasoline before the power is affected adversely.

A few data are given for tests with alcohol and water mixture to show the possibilities of obtaining high power for emergency use, full throttle take-off, full throttle climbs, etc.

Special Fuels

Pistons to obtain a compression ratio of 7.7 were designed and fabricated at this Division for the R-1340-15 engine. Tests with this compression ratio could be made only at reduced power with 87 octane fuel. A mixture control calibration, based on 490 b. hp. at 2200 r.p.m., part throttle, using California gasoline plus 11 cc. of lead, furnished the following results: Maximum power specific fuel consumption—0.435 lb. per b. hp. per hour; maximum economy—0.400 lb. per b. hp. per hour; first signs of detonation occurred at 0.425 lb. per b. hp. per hr.; maximum average head temperature—443 deg. fahr.; and maximum average flange temperature—272 deg. fahr. A mixture control calibration at 2200 r.p.m. full throttle, using 20 per cent water and 80 per cent ethyl alcohol, by weight, for fuel gave the following results: Maximum brake horsepower—710; maximum power specific fuel consumption—0.920 lb. per b. hp. per hour; maximum economy—0.855 lb. per b. hp. per hr.; maximum average head temperature—338 deg. fahr.; and maximum average flange temperature—235 deg. fahr. With this same fuel, 800 b. hp. was developed at 2600 r.p.m. It will be noted by comparison of these results that the cylinder temperatures with the water-alcohol mixture are considerably lower than with the gasoline mixture, even though the horsepower output with the water-alcohol mixture is 220 b. hp. more.

In conclusion, it is desired to state that if full advantage is taken of all the possibilities left untouched and incompleted to date, for improving the efficiency of the Otto cycle, with induction system fuel injection, as developed by the Air Corps, a gain of approximately 12 per cent could be realized above the best performance listed in this paper. There are many possibilities for increasing the efficiency by modification of the Otto cycle and it is believed that fuel injection will lead the way towards such modifications.

Acknowledgments

The author wishes to express his appreciation to officers of the Air Corps and especially to Capt. E. M. Powers, Chief of the Power Plant Branch, for permission to publish the information contained in this paper. Also, to express his gratitude to the many persons connected with the fuel injection project and especially to his immediate adviser, Opie Chenoweth, who at one time was charged with the fuel injection project; to his co-worker, R. E. Hoffman; to the Carburetor Unit master mechanic, H. H. Stickney; and to the excellent services of R. W. Clark, dynamometer operator. The services rendered by M. G. Chandler, the inventor of the injector which was developed, and promoter of many valuable related ideas, and his co-worker, W. J. Cooke, were beyond evaluation in assuring the success of this project.

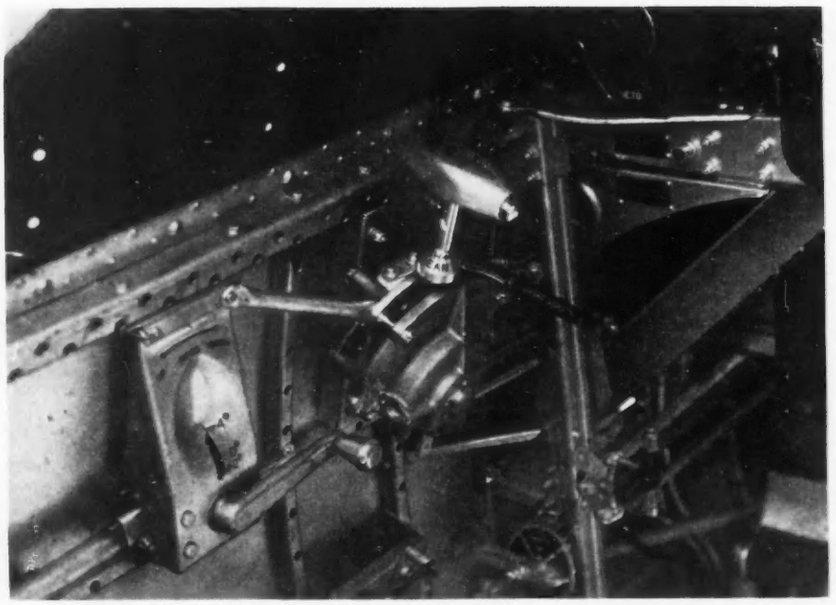


Fig. 20—Engine control unit used with E-250-R fuel injector and related equipment, installed in Boeing YP-12K airplane.

Flame Movement and Pressure Development in Gasoline Engines

By Clarke C. Minter
Consulting Chemist

COMBUSTION roughness is defined as the ratio of the rise in pressure to the time required for the burning. It is pointed out that evidence shows that the time required to burn a charge in an engine is directly proportional to the volume of the charge.

A measure of the "natural roughness" of a combustion chamber is given by the ratio of the compression pressure to the clearance volume.

The question of how flame speed varies during the burning is taken up and it is brought out that flame speed goes through a maximum when half the volume of the charge is burned.

In designing a combustion chamber for smoothness of burning, it is necessary to consider the variations in the speed of flame propagation, and to attempt to bring the maximum speed early in the burning so as to get the flame off to a good start. In this manner it is possible to avoid unduly rapid increases in pressure at a late stage of the burning. This is accomplished by considering the "volume distribution" of the combustion chamber around the point of ignition, a procedure introduced by Janeway. It is thus possible for the maximum flame velocity to occur at any stage of the burning simply by varying the distribution of volume to produce the desired result.

Experience has shown that the point at which maximum flame speed occurs must come early in the burning in order to obtain smooth combustion. The exact location of the point of maximum flame speed will depend on the clearance volume and the compression pressure.

SEVERAL years ago, Taub[1] summarized the work of three engineers who had made valuable contributions to the art of combustion-chamber design. It is hardly necessary to say that the three engineers referred to are Ricardo, Whatmough and Janeway. The object of the investigations undertaken by these engineers was to determine the fundamental causes of combustion roughness in gasoline engines, and to design combustion chambers that gave smooth combustion.

Of the three investigators named, Janeway appears to have been the only one to attempt to solve the problem—of combustion roughness by considering the fundamental mechanism—of flame movement in closed vessels. Ricardo makes no assumptions, and does not go into the question of flame movement and pressure development except in a rather limited experimental investigation, leaving the theoretical side of the problem untouched, at least in his papers. Whatmough alludes to the physical chemistry of combustion and flame propagation, but discusses familiar phenomena in such vague terms that it is difficult to detect where any principles of physical chemistry are applied to the problem.

What is Combustion Roughness?

It is generally agreed that roughness is due to a very rapid increase in pressure at some stage of the burning. Two curves that show the difference between rough and smooth combustion are shown in Fig. 1. In this case the total time elapsing between ignition and maximum pressure is the same, but one combustion chamber is rough and the other smooth.

Ricardo obtains smoothness by designing a combustion chamber in which the plug is located in a shallow pocket over the intake valve. Apparently, the flame gets off with no delay on account of the "attraction" by the large volume adjacent to the pocket. Whatmough gets his flame off to a good start by firing from the hot zone over the exhaust valve, and obtains smooth results. Janeway calculates how the volume of the combustion chamber should be distributed around the plug so that very rapid increases in pressure can not occur. In every case there seems to be an effort on the part of the designer, conscious or unconscious, to get the

[This paper was presented at the Annual Meeting of the Society, Detroit, Jan. 18, 1935.]

[1] See S.A.E. JOURNAL, October, 1930, p. 413.

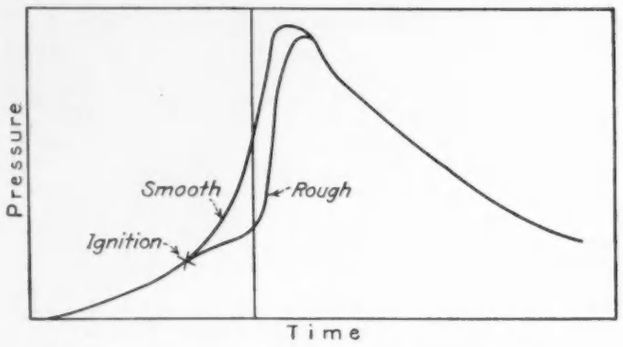


Fig. 1—Comparison of Smooth and Rough Combustion

flame off to a good start with as little lag as possible and to give the flame as long a run as possible by placing the plug over the valves. This leads to a quantitative measure of roughness which is simply:

$$\text{Combustion Roughness} \propto (P_2 - P_1)/(t_2 - t_1).$$

The reason the question of combustion roughness has become important in the last few years is that combustion chambers have been becoming smaller. It is apparently not generally recognized that the time required to burn a charge is directly proportional to the volume of the charge. Ricardo[2] has published a curve showing the variation of optimum spark advance with compression ratio, and analysis of this curve shows that optimum spark advance is directly proportional to $1/(r-1)$, or to the clearance volume. This relation has also been checked experimentally by Minter and Finn[3].

Not only are combustion chambers becoming smaller on account of increasing the compression ratio, but the tendency toward multiplication of cylinders without a corresponding increase in displacement has the effect of reducing the size of the combustion chamber for a given displacement.

Comparing two engines, an eight-cylinder and a six-cylinder, both of 200-cu. in. displacement and 5.5 compression ratio, it is found that the clearance volume for the eight is 5.55, and for the six, 7.4. Since the time required to burn the charge is directly proportional to the clearance volume, the combustion period for the eight is only 75 per cent—5.55/7.4—as great as the combustion period for the six. The increase in pressure being about the same in both engines, it seems that the "natural" roughness of the eight is greater than that of the six. Of course, increasing the compression ratio brings about roughness also, not only because the charge burns in a shorter time, but the increase in pressure is greater at the higher ratios.

According to the definition of roughness just given, the smaller the combustion chamber is, the greater is the combustion roughness. This does not mean necessarily that decreasing the displacement per cylinder will make the complete engine, say an eight, run less smoothly than a six of the same total displacement. Although in the eight the combustion period is shorter than in the six, the piston will most likely be smaller in diameter in the eight, and the combustion roughness of the eight might not appear to be any greater than in the six.

To be able to predict what sort of pressure-time curve would be obtained with a given combustion chamber is not an easy matter. The method followed in this paper has been reduced to its simplest terms for purposes of presentation. This by no means pretends to be a full account of all the complex phenomena of flame propagation and pressure development, as only those points which can be applied are discussed.

[2] See High-Speed Internal-Combustion Engines, by H. R. Ricardo; p. 47, Fig. 16.
[3] See *Automotive Industries*, July 18, 1931.

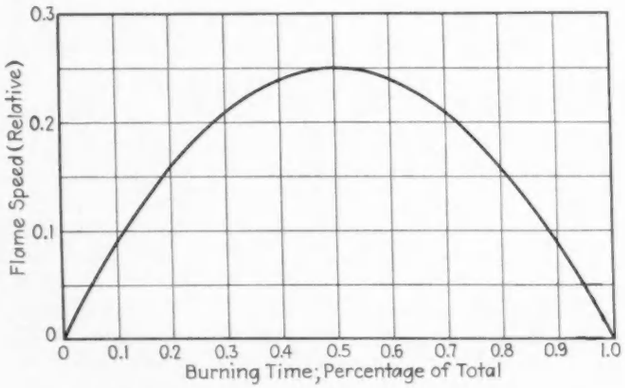


Fig. 2—Variation of the Flame Speed as the Charge Burns. See Table 1, Appendix 1.

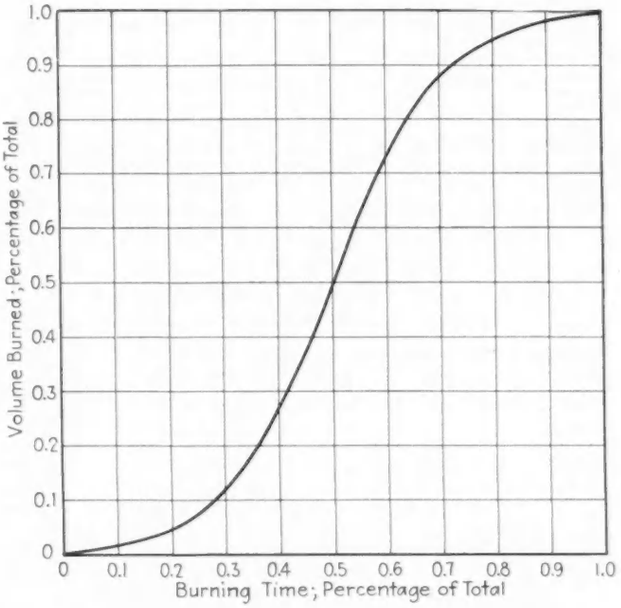


Fig. 3—Flame Travel and Volume Burned as a Function of Time. See Equation (2), Appendix 1.

The essential knowledge is as follows:

(1) Mechanism and speed of flame propagation.

(2) The relation between pressure developed and volume of combustion products.

(3) Distribution of volume around the spark-plug.

The first two essential factors are fundamental and general in application. The third factor is particular and applies only to the combustion chamber under consideration.

Mechanism of Flame Propagation

The movement of flame in closed vessels has been extensively studied in bombs of various sizes and shapes. All

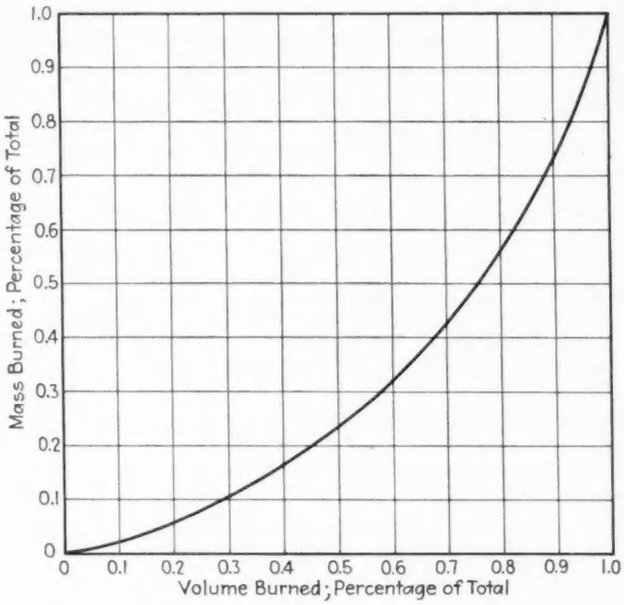


Fig. 4—Relation between Mass of Charge and Volume of Combustion Products. See Equation (5), Appendix 2.

evidence shows clearly that flame speed goes through a maximum at about the midpoint of its travel. Fig. 2 shows how flame speed varies with distance of travel. Fig. 3 gives the distance traveled by the flame as a function of time. This

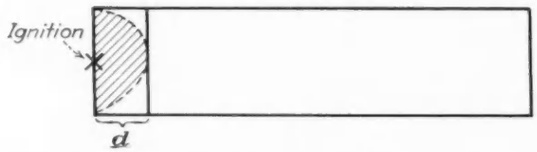


Fig. 5—Plain Cylindrical Bomb, with Ignition in the Center of One End

The flame has traveled the distance *d*. The shaded portion shows the volume of combustion products.

sigmoid, or s-shaped curve, is characteristic of all flame movement in closed vessels with the possible exception of the sphere.

The combustion chamber of a gasoline engine is no exception. The excellent photographs obtained by Withrow and Boyd[4], of the General Motors Research Corp., show that the movement of the flame front in their combustion chamber had the same characteristics as in a bomb. Glyde[5] followed the movement of flame across a combustion chamber through a series of windows viewed through a stroboscope and reported that the speed of the flame went through a maximum. Marvin and Best[6], and, recently, Marvin[7], using the same method employed by Glyde, but greatly improved, show that flame speed goes through a maximum half-way across the combustion chamber.

It is, therefore, not clearly understood what Janeway[8] means when he says that "flame speed is proportional to some power of the pressure." Since the pressure does not go through a maximum except at the end of the burning, the flame speed cannot be proportional to the pressure alone. Janeway is right when he says that the "reaction velocity," or the rate at which the fuel burns in the flame, is proportional to the temperature, or to some power of the pressure. But reaction velocity is not the only factor governing flame velocity. The rate of expansion of the combustion products must also be considered. The treatment of this problem is given in Appendix 1.

Relation between Pressure and Volume of Combustion Products

Janeway has derived a relation between the volume of combustion products and the pressure developed at any instant. Although his relation is based on thermodynamics, it is slightly in error because he assumed that the combustion products behind the flame front expand isothermally. It has been shown by David and Davies[9] that the combustion products in a bomb undergo an adiabatic compression, rising in temperature about 80 deg. cent. after the flame has passed a given point near the source of ignition.

In Appendix 2, a relation similar to that of Janeway has been derived from simple considerations, and gives results slightly different from the relation derived by Janeway. Fig. 4 shows how the fraction of the total volume occupied by the combustion products varies with the fraction of the total mass burnt at any instant. Since the pressure developed is proportional to the mass of charge burnt, it is simple to calculate the relation between pressure developed and volume occupied by combustion products.

Volume Distribution

Janeway's contribution to the problem of combustion-chamber design consists principally in his determination of the distribution of volume around the point of ignition. That is, if the flame front is considered as spreading spherically from the spark plug, the volume of the charge which has

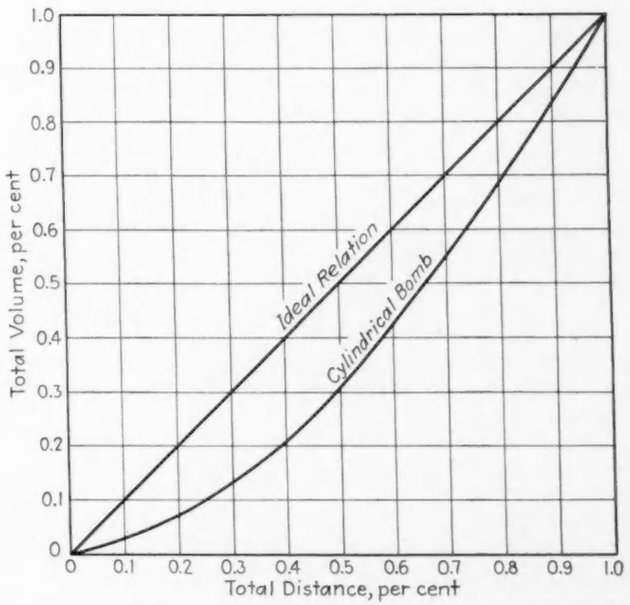


Fig. 6—Volume Distribution for the Type of Bomb Shown in Fig. 5.

[4] See *Industrial and Engineering Chemistry*, vol. 22, 1930, p. 539.
[5] See *Journal of the Institute of Petroleum Technologists*, vol. 16, 1930, p. 756.
[6] See N.A.C.A. Technical Report No. 399, for 1931.
[7] See S.A.E. Journal, November, 1934, p. 391.
[8] See S.A.E. Journal, May, 1929, p. 511 and 512.
[9] See *Philosophical Magazine*, Series 7, 1930, p. 1043.

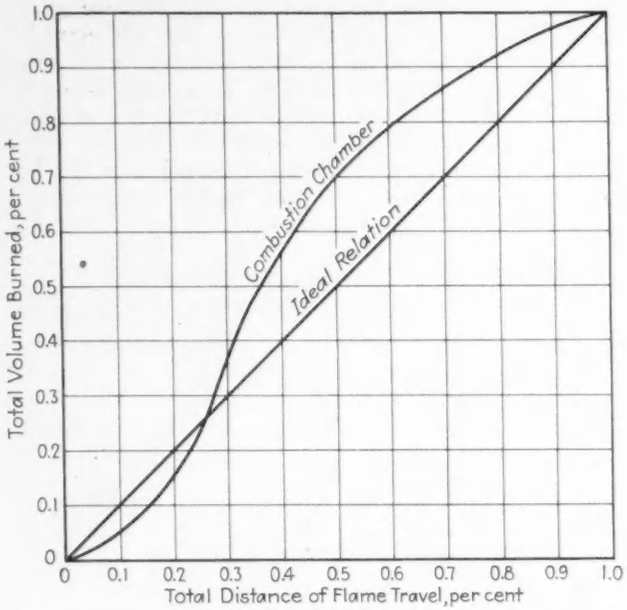


Fig. 7—Typical Volume-Distribution Curve for a Combustion Chamber

been burned at a given distance from the plug will depend on the shape of the combustion chamber and the position of the plug.

The question of volume distribution has apparently been overlooked until Janeway called attention to its importance. This is surprising because, in even the simplest type of bomb, it is easy to see that the distance of flame travel and the volume burned are not linearly related. Take, for example, a plain cylindrical bomb, with ignition in the center of one end, as in Fig. 5. It is clear from Fig. 5 that, when the flame first starts, there is considerable difference between the distance traveled and the fraction of the volume burned. This difference becomes less as the flame moves forward, and the two variables coincide at the end of the burning.

Fig. 6 shows a linear relationship between distance of flame travel and the volume burned, and there is also given the relation between the variables for the type of bomb shown in Fig. 5.

Instead of lying below the ideal relation shown in Fig. 6, combustion chambers are so shaped that, for the most part, the curve showing volume burned against flame travel lies above the ideal linear relation. A typical volume-distribution curve for a combustion chamber is shown in Fig. 7. This curve does not take into account the changes in volume due to the movement of the piston; and, for purposes of comparison of different designs, the piston movement need not be considered. However, in order to calculate the pressure-time curve for the burning, the movement of the piston has to be considered.

Janeway apparently calculated the distribution of volume in the combustion chambers he developed. It must have been a very tedious process. It is much simpler and easier actually to determine the distribution of volume in a combustion chamber. A neat method for doing this has been developed by the Chevrolet Engineering Department. It consists in cutting out spherical portions from the combustion chamber with a special tool, and determining the volume after each cutting by immersion of the remainder. In this manner it is possible to determine the fraction of the total volume burned at any position of the flame front.

To illustrate more clearly the importance of volume distribution, and its effect on the position of maximum flame-speed, conical bombs will be employed. These illustrations have already been employed by Taub for the same purpose.

In Fig. 9 are shown three bombs which give widely different volume-distribution curves. In the cylindrical bomb with multiple ignition, we have a plane flame-front and a linear volume-distribution curve as shown in Fig. 10. The volume burned as a function of time is shown in Fig. 11, and the point at which maximum flame-speed occurs in Fig. 12.

The volume-distribution curves for the cone with ignition at the apex and at the base show widely different characteristics, as can be seen in Fig. 10. Fig. 12 shows how the point of maximum flame-speed varies with the volume-distribution curve for the two cases. It is easy to see that, with ignition at the apex, the running will be rough because the maximum flame-speed occurs so late in the burning. On the other hand, since the maximum flame-speed occurs early with ignition at the base of the cone the running will be smooth.

The reason for this will be clear from Fig. 4. Since the flame speed is a maximum when half the total volume is burned, it can be seen that at that point slightly less than one-fourth the pressure has been developed. This means that more than three-fourths of the pressure rise occurs after the flame speed is a maximum. If this large proportion of the pressure rise occurs in a short time, as would be the case with the cone and ignition at the apex, it is easy to see how combustion roughness would occur. Smoothness would be obtained only by bringing the maximum flame-speed early in the burning, so that three-fourths of the pressure rise would occur in something like three-fourths of the total burning time. The statement made earlier that designers attempt to get the flame off to a good start becomes clear when this point is understood.

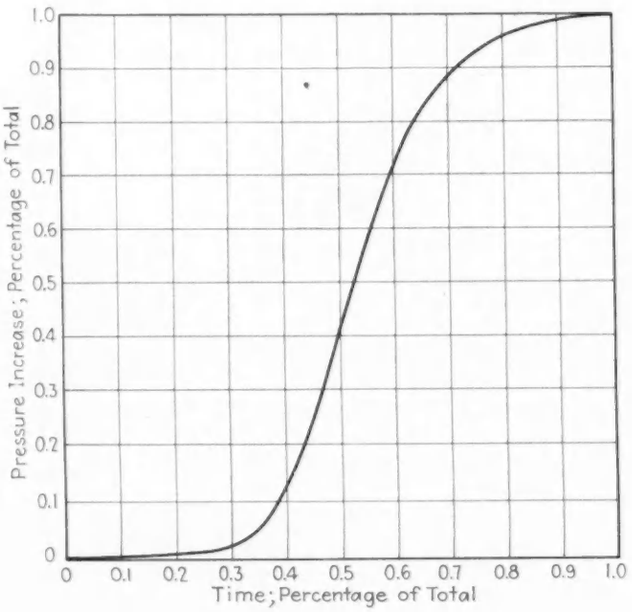


Fig. 8—Synthetic Pressure-Time Curve—Not Corrected for Piston Movement—for the Combustion Chamber for Which the Volume-Distribution Curve Is Shown in Fig. 7.

Another point about the pressure-time curves is that the first derivative of the curve gives the area of the flame-front. While this is a measure of the rate at which the charge is being burned, it is not the whole measure. Flame speed also has to be taken into account. By bringing the maximum area of the flame front early in the burning, it is observed that the combustion is smooth. This is really an attempt by the designer to bring the maximum flame-speed early in the burning, so that the flame will get off to a good start. Smooth combustion chambers have that distribution of volume which brings the maximum flame-area early in the burning; and, naturally, the maximum flame-speed will occur early. A good rule to follow in designing combustion chambers for smoothness is simply—*burn half the volume of the charge as quickly as possible.*

Even though the flame front is not truly spherical, determination of the distribution of volume around the plug in the manner outlined above will give results that are sufficiently

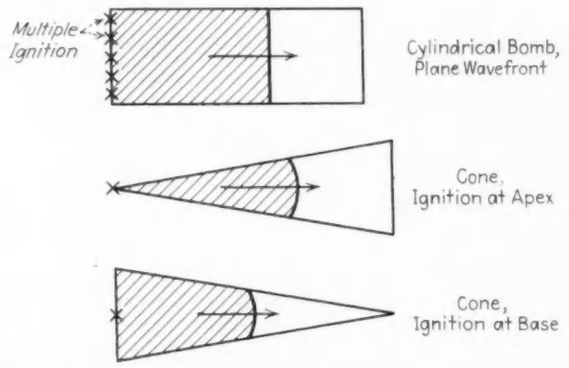


Fig. 9—Three Bombs Which Have Widely Different Volume-Distribution Curves

accurate for comparing different designs of combustion chambers. After all, it seems that it is the product of the magnitudes of the unburned volume and the burned volume that controls the rate of flame propagation, as pointed out in Appendix 1. Since the maximum rate of flame propagation occurs when half the volume of the charge has been burned, it is the purpose of the designer so to distribute the volume around the plug that the maximum rate of flame propagation occurs at any desired point in the burning period.

It has already been mentioned that, in designing for smooth combustion, engineers attempt to get the flame off to a good start. This point is brought out clearly in Fig. 1. This result appears to be accomplished by distributing the volume in such a manner that maximum rate of flame propagation occurs when the flame has traveled about one-third of the distance from the plug to the most remote part of the combustion chamber. It is easy to see how this scheme would give the flame a good start, and prevent the lag exhibited by the example of roughness in Fig. 1.

Synthesis of Pressure-Time Curves

If the volume of charge burned were a linear function of the distance traveled by the flame, then Equation (2) in Appendix 1 would apply equally well to the variation of the volume burned and the distance the flame travels in time. However, since the volume is never linearly related to the flame travel, it is better to consider Equation (2) in Appendix

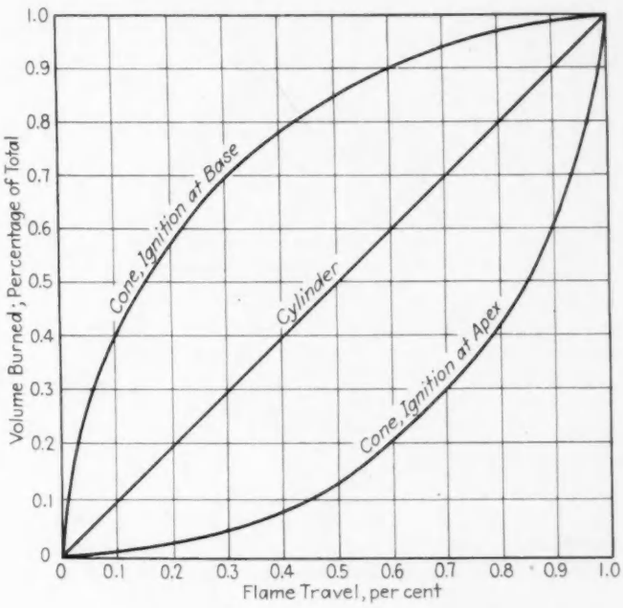


Fig. 10—Volume-Distribution for the Bombs Shown in Fig. 9

1 as applying specifically to the variation of the distance of flame travel in time.

By means of the volume-distribution curve, such as that given in Fig. 7, it is possible to find how the volume burned varies with time. Making use of Equation (6) in Appendix 2, which gives the relation between the pressure developed and the volume burned, we can then construct a pressure-time curve for the combustion chamber. Such a curve is shown in Fig. 8, which gives the pressure-time curve for the combustion chamber, the volume-distribution curve of which is given in Fig. 7.

It should be pointed out that the pressure-time curve of

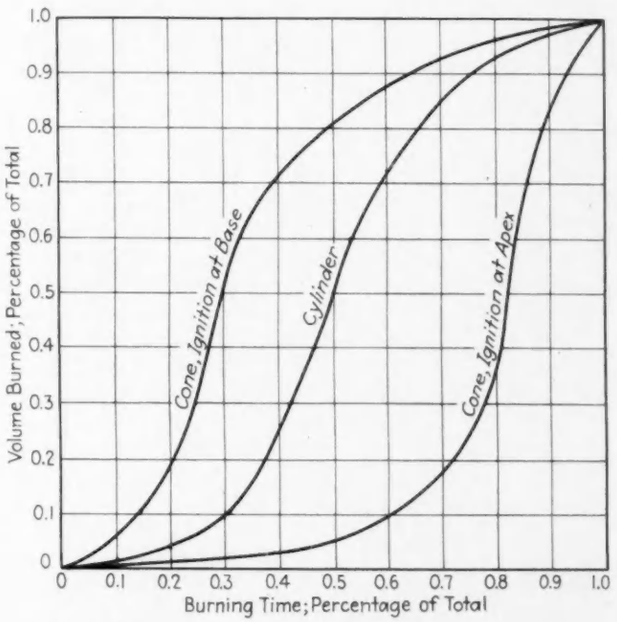


Fig. 11—Volume Burned as a Function of Time for the Three Types of Bombs Shown in Fig. 9

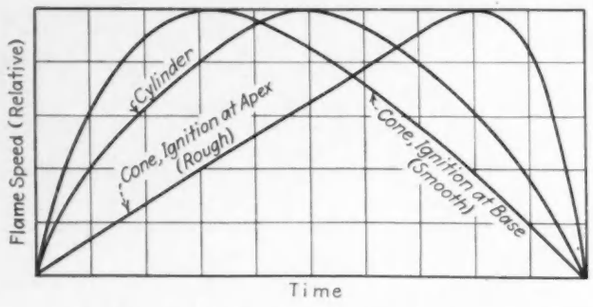


Fig. 12—Curves Showing the Point of Maximum Flame Speed in the Three Types of Bombs Illustrated in Fig. 9

Fig. 8 has not been corrected for movement of the piston, and does not represent the true pressure-time curve that would be obtained experimentally with a suitable indicator. Since the object of this discussion is to formulate a basis of comparison of combustion chambers for roughness or smoothness of combustion, whether we obtain the true pressure-time curve is not important.

It has already been brought out that flame speed goes through a maximum when half the volume of the charge has been burned. It has also been mentioned that the volume of a combustion chamber should be so distributed that the maximum flame velocity occurs when the flame has traveled about one-third of the distance of greatest travel. This will insure that the flame gets away to a good start, without undue lag, and that the combustion will be smooth.

In conclusion, it should be mentioned that volume-distribution studies will yield more valuable comparative results if the movement of the piston is taken into account. Unless piston movement is considered, there is an error both at the beginning and at the end of the burning process. While the procedure is a little more complex than that used in the past, it can be developed into a routine method of practical value.

Appendix I—Calculation of Flame Speed

Since flame speed goes through a maximum as the charge burns, the speed must be the product of two variables, one of which is increasing and one decreasing as the flame advances. Since expansion velocity decreases and reaction velocity increases, we can assume that the flame speed is proportional to the rate of expansion of the combustion products and to the rate at which the fuel burns in the flame.

It is clear that the rate at which the combustion products expand is directly proportional to the volume of the unburned charge, and we can further assume that the rate of reaction in the flame is directly proportional to the volume of combustion products. Employing these assumptions, let y be the fraction of the total volume burned in the fractional time t; then the rate of flame travel is:

$$dy/dt = ky(1-y) \tag{1}$$

Integrated, this expression becomes, finally:

$$y = \frac{1}{1 + 148e - 10t} \tag{2}$$

where t is a fraction of the total time, and y is the fraction of the total volume burned. See Fig. 3.

Expression (1) shows very clearly that rate of flame propagation goes through a maximum when half the volume is burned in half the time. See Fig. 2.

TABLE I—VALUES OF THE SEVERAL FACTORS

y	$1-y$	dy/dt From (1)
0.1	0.9	0.09
0.2	0.8	0.16
0.3	0.7	0.21
0.4	0.6	0.24
0.5	0.5	0.25
0.6	0.4	0.24
0.7	0.3	0.21
0.8	0.2	0.16
0.9	0.1	0.09
1.0	0	0

It is also clear that the second derivative of Expression (2) shows that the acceleration of flame movement is greatest when the flame first starts to move. The acceleration decreases regularly and becomes negative after the flame has traveled half way through the combustion chamber.

Appendix 2

The relation between pressure and volume of combustion products is derived as follows: At any instant let

x = fraction of total mass of charge burned
y = fraction of total volume of charge burned
$1 - x$ = fraction of total mass of charge unburned
$1 - y$ = fraction of total volume of charge unburned

If the original mass is M and the total volume V, then the mass unburned is $M(1 - x)$ and the volume occupied by the unburned charge is $V(1 - y)$.

Since density is given by the ratio of mass to volume, the density of the unburned charge is

$$s_2 = \frac{M(1-x)}{V(1-y)} \tag{1}$$

But $M/V = s_1$, the density of the original charge. Hence,

$$s_2 = s_1\frac{1-x}{1-y} \tag{2}$$

Since the unburned charge is compressed adiabatically, the pressure ahead of the flame is

$$p_2 = p_1\left(\frac{1-x}{1-y}\right)^{1.33} \tag{3}$$

where 1.33 is the ratio of the specific heats and p_1 is the compression pressure.

The pressure in the burned portion is

$$p_2 = p_1(1+kx).$$

Since

$$p_2/p_1 = 4.13,$$

when p_2 is the maximum pressure, and $x = 1$, $k = 3.13$ and

$$p_2 = p_1(1+3.13x) \tag{4}$$

Equating (3) and (4), we find the relation between mass of charge burned and volume of combustion products to be

$$y = 1-\frac{1-x}{(1+3.13x)}1.33 \tag{5}$$

Values from this equation are plotted in Fig. 4. It is interesting to note that the expression $(1 - x)/(1 - y)$ in (3) approaches the maximum value 2.90. Hence, the relation between the maximum pressure and the compression pressure is

$$p_m = p_c(2.90)^{1.33} = 4.13,$$

a result which is well known.

The final expression relating pressure and volume of combustion products is

$$p_2 = p_c\frac{1}{(1-0.656y)}1.33 \tag{6}$$

Surface and Shape Characteristics of Cylinder Bores

By Kirke W. Connor
President, Micromatic Hone Corp.

THE subject is treated under the headings of cylinder-wall wear, measurement of surface finish, honing engine-cylinder bores, distortion of cylinders, and service-equipment influence on cylinder-block design. Special tools are illustrated and described, and charts showing the results attained are presented.

The contributory causes of cylinder wear are mentioned, the profilograph instrument for studying the various degrees of surface finish is described and the process of honing cylinder bores is stated. It is said that there is a direct relation of cylinder-wall finish and accuracy to engine performance.

Six essential features of service equipment are discussed. In conclusion, a method that keeps grit and chips out of the crankcase is described, together with tools and methods adapted to the service field.

THE fact that the cylinder-assembly parts of any internal-combustion engine deteriorate at a much more rapid rate than any other of the component parts is well known. For this reason, the subject of this paper is of especial interest. It is gratifying that, through the general activities the Society, the automotive, aircraft and Diesel-engine industries are of such material assistance to each other. With the introduction of the newer-type high-speed Diesel-engine, now offered for automotive power-units, we find many factors closely related to the characteristics of automobile engines.

The five subdivisions of the subject are treated herein under the headings: Cylinder-wall wear, measurement of surface finish, honing engine-cylinder bores, distortion of cylinders, and service-equipment influence on cylinder-block design. No attempt is made to draw definite conclusions; the honing process is so closely associated with features of accomplishment in bettering the conditions referred to that the author simply solicits the readers' interest from a general, informative viewpoint.

[This paper was presented at the Tractor and Industrial Power Equipment Meeting, Chicago, Dec. 5, 1934.]

Cylinder-Wall Wear

Cylinder wear is a complex phenomenon and has a number of contributory causes. On first consideration, we might conclude that cylinder-wall wear would be in direct ratio as to the hardness of the materials used. This theory might be projected from the standpoint that the wear to cylinder-assembly parts is primarily due to abrasion resulting from grit or dirt drawn into the engine with the air consumed with the combustion mixture. However, we find that piston

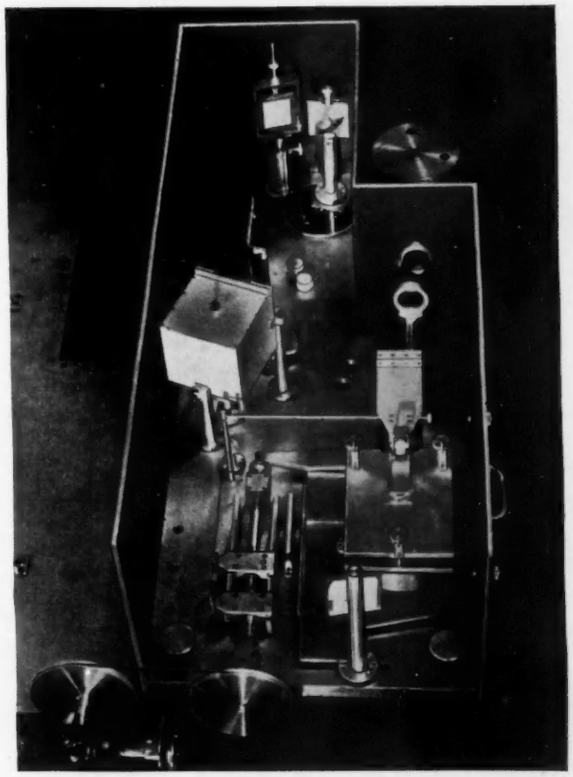


Fig. 1—Full View of the Profilograph Instrument

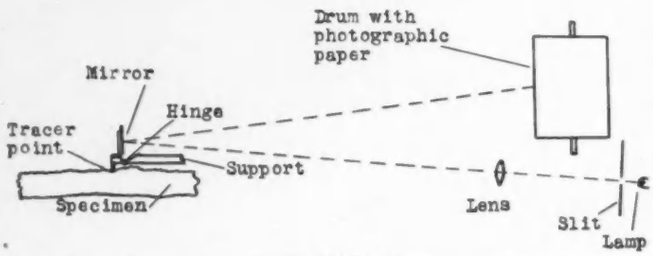


Fig. 2—Fundamental Principle of the Profilograph

and ring wear are seriously affected, as the hardness of the cylinder walls is increased unless the cylinder bores are finished to a very high degree of smoothness. One authority claims to find that there is no decided improvement in cylinder wear unless a hardness of 450 Brinell or upward is used; whereas, the chief metallurgist of one of the larger automobile manufacturers is of the opinion that a Brinell hardness of from 220 to 230 is not so desirable, from the standpoint of wear, as is softer iron ranging from 190 to 200. This view is based on the theory that the higher graphite-content of the softer irons serves, to a certain extent, as a lubricant.

The average rate of wear with automobile engines seems to be approximately 0.0005 in. on the diameter per 1000 miles of travel. Expressed in hours of operation, one authority determines the cylinder-wall wear of the average gasoline engine to be 0.003 to 0.004 in. per 1000 hr. of running. These figures represent a terrific rate of deterioration; but it is appalling to consider that at least one authority has determined that the wearing factor with airless-injection oil-engines is 75 per cent greater than with the conventional type of gasoline engine.

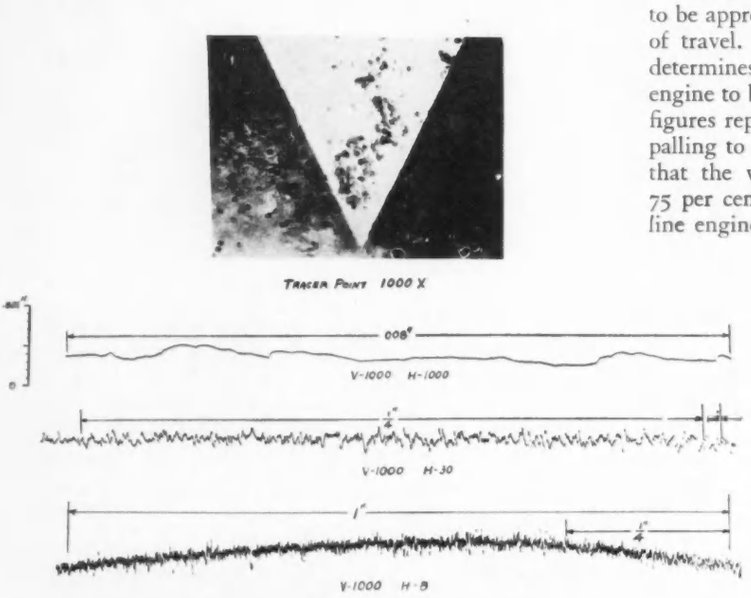


Fig. 3—Diamond Point of the Profilograph and Sample Profilograph Records

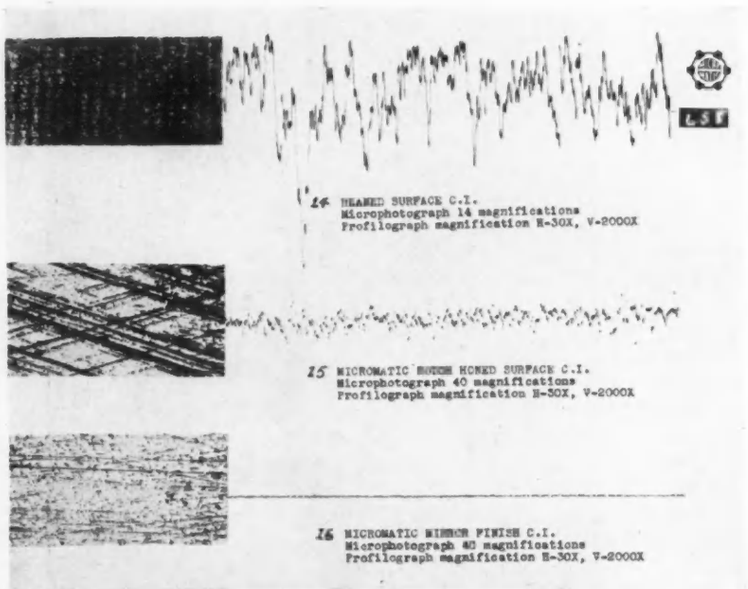

14 REAMED SURFACE C.I.
Microphotograph 14 magnifications
Profilograph magnification H-30X, V-2000X
15 MICROMATIC SMOOTH HONED SURFACE C.I.
Microphotograph 40 magnifications
Profilograph magnification H-30X, V-2000X
16 MICROMATIC MIRROR FINISH C.I.
Microphotograph 40 magnifications
Profilograph magnification H-30X, V-2000X

Fig. 4—Profilograph Record of Reamed, Rough-Honed and Mirror-Finished Surfaces

Fig. 6—Full-Automatic Honing-Tool

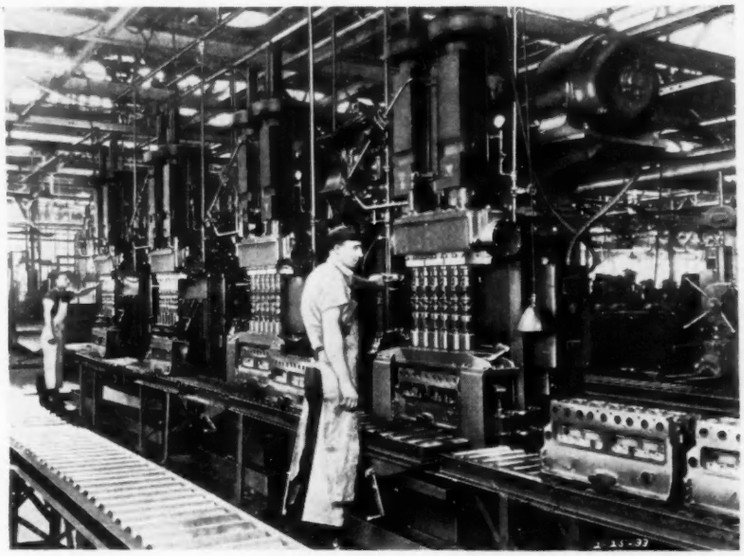


Fig. 5—Production Line in One Plant

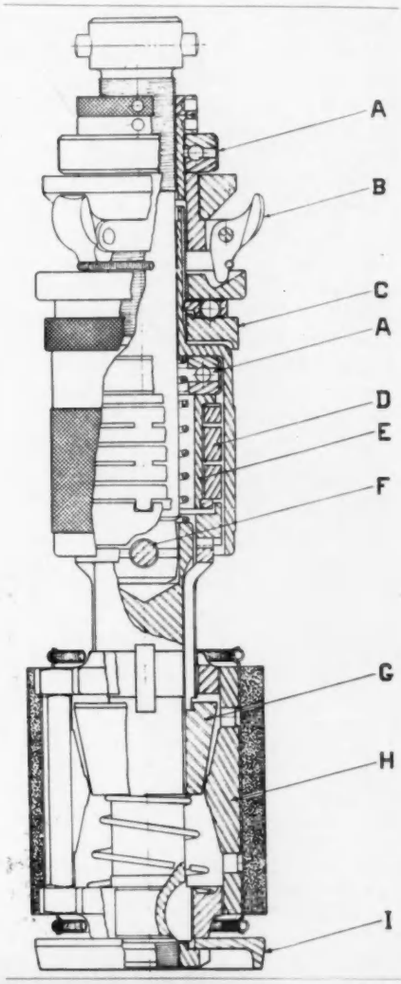
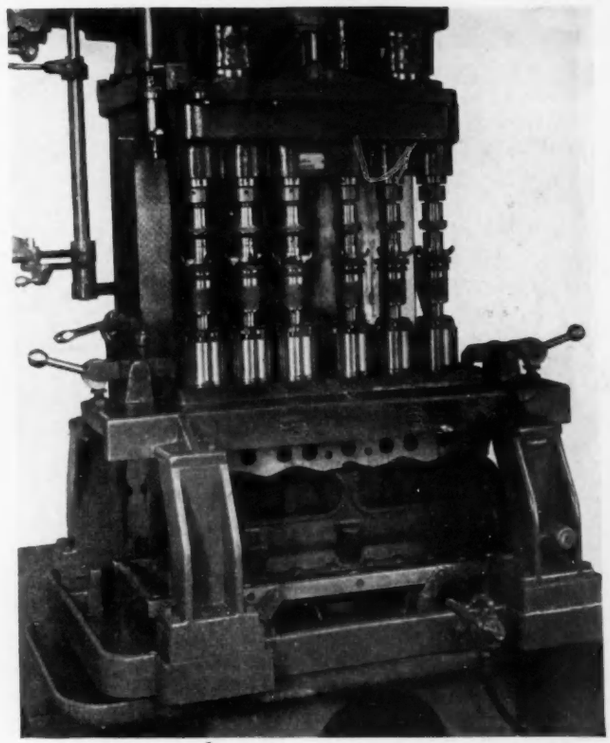


Fig. 7 *(right)*—Assembly Drawing of a Full-Automatic Honing-Tool

Fig. 8 *(below)*—Six-Spindle Automatic Honing-Machine



The hammering action of the piston rings against the cylinder walls is responsible for no small part of cylinder wear. In fact, the pressure behind the top rings has been determined to be approximately 85 per cent of the compression force in the combustion chamber at the time of ignition. In the case of the average automobile engine, this amounts to an excess of 500 lb. per sq. in. This, undoubtedly, is one of the contributing causes to the excessive wear at the upper end of the ring travel. In fact, cylinder wear diminishes from the top to the bottom of the ring travel in somewhat the same proportion as the combustion pressures decrease with the downward movement of the piston. The mirror-smooth cylinders, as now being used by the American motor-car manufacturers, are credited with having the feature of withstanding the hammering of the rings due to the fact that the *base-metal surface* is not contracted or compressed by this action. At the same time, this hammering action is very probably responsible for the fact that the piston rings come into a seat reasonably soon when operated on mirror-finished cylinders. In this case, the turned surface of the piston ring, being rougher than the mirror-finished cylinders, is compressed by the hammering action, so that the ring soon fits the contour of the cylinders.

From the recent data[1] compiled by H. R. Ricardo, it is indicated that the corrosive action resulting from products of combustion most largely contributes to cylinder-wall wear in the case of gas engines as well as oil engines. Working experience with the heavy-fuel injection-type has brought out the fact that a choice of fuel—particularly avoiding the range which has high ignition-temperatures—has a very important bearing on the rate of wear. However, it seems evident that, in any case, high condensation resulting from overcooling has the seriously bad effect of inducing corrosion In fact, one report given in the I.A.E. JOURNAL states that it was concluded that low cylinder-wall temperatures—below 90 deg. cent.—are the *main* cause for cylinder-wall wear. This might be taken to account for the rapid wear experienced when delayed warming-up takes place, especially if accompanied by scanty lubrication.

[1] See *Journal of the Institution of Automobile Engineers*, March, 1933; and June, 1933, for the Interim Report.

The theory of corrosion as being of relatively greater importance than abrasion is again substantiated by the experience of most marine-engine builders as compared with motor-car and tractor manufacturers. Very little, if any, dust or grit are drawn into the engine and the higher rate of cylinder wear is quite likely due to over-cooling, afforded by the facilities at hand during operation. Again substantiating the corrosion or erosion theory, we know that air-compressor cylinders, as well as refrigerator units, show relatively little wear; and it is thus evidenced that the products of combustion must have their effects. Inasmuch as speed does not seem to be a contributing force to the wearing property, as concerns erosion or etching of the surface, and due to the fact that no difference in wear is apparently due to the use of either aluminum or cast-iron pistons, it is a fair assumption that localized cylinder wear might be caused by erosion at the points of blow-by due to cylinder-bore distortion.

It is suggested that the degree of finish be taken into consideration when combating the effects of corrosion as indicated by the fact that stainless steel, for example, is not stainless until polished. In other words, a rough surface is much more easily etched by a surface-contacting action than is a smooth surface. Very probably this is one of the reasons why the initial wear of automobile cylinders has been further reduced by the use of the mirror honed-finish. It has, in general practice, been found that a smooth surface sets up a greater resistance to wear, not only of itself but it imparts the same effect to other contacting parts and, in this respect, smooth cylinder walls have, of course, contributed to increasing the life of piston rings.

Measurement of Surface Finish

For the purpose of studying the various degrees of finish produced by different machining operations, the profilograph instrument developed at the University of Michigan, shown in Fig. 1, has been found invaluable. For the benefit of those who are not familiar with this device, it not only measures surface roughness accurately within millionths of

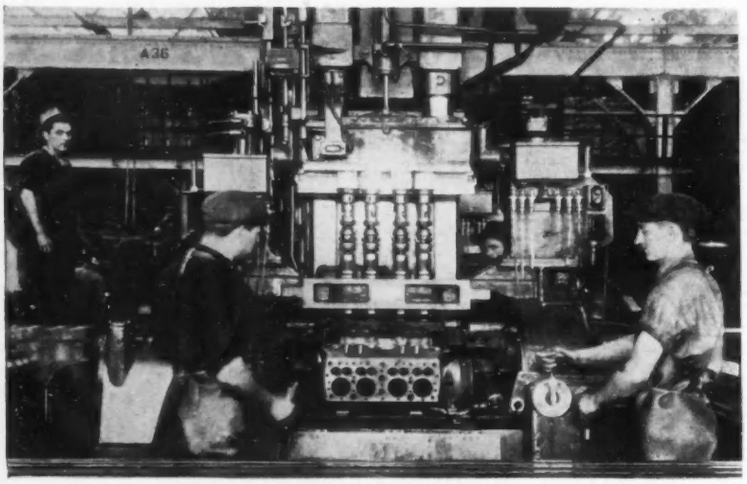


Fig. 9—Vertical Honing-Machine in Operation

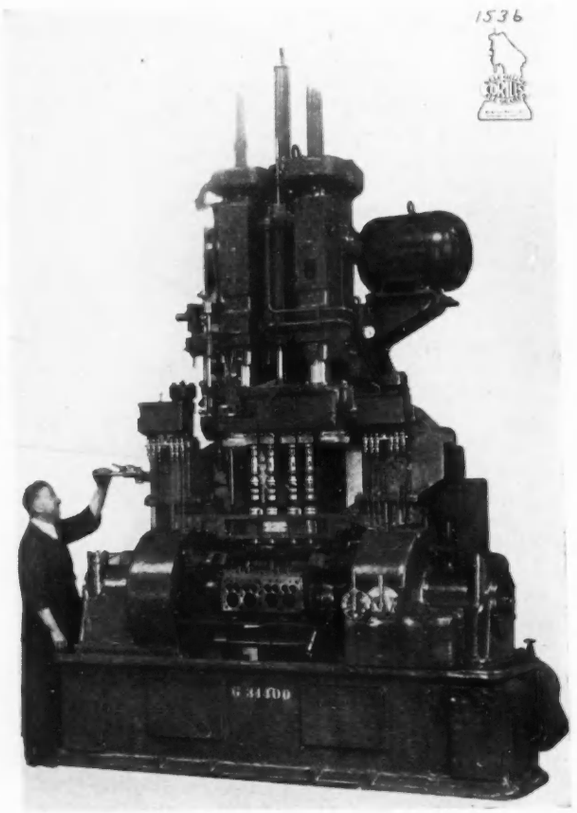


Fig. 10—Vertical Hydraulic Honing-Machine

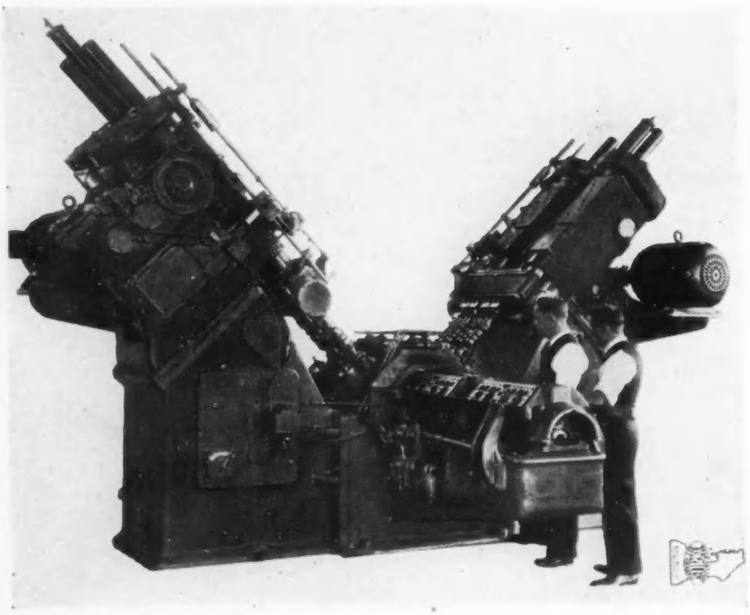


Fig. 11—Angle-Type Hydraulic Honing-Machine

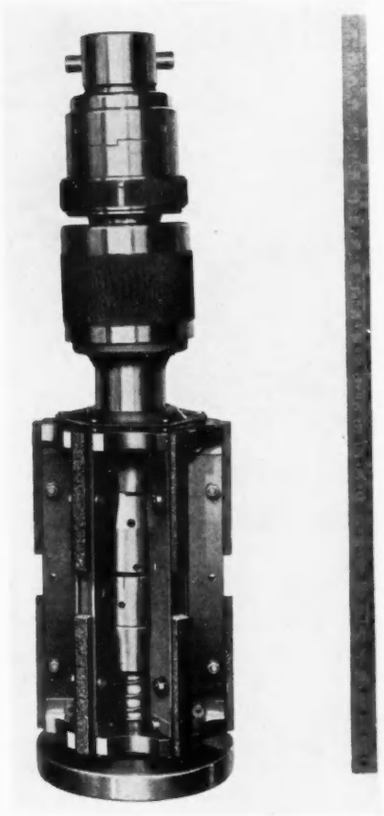


Fig. 12—Semi-Automatic Heavy-Duty Honing-Tool

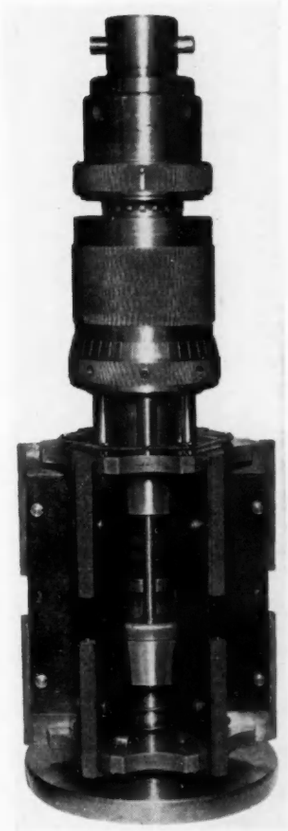


Fig. 13—Semi-Automatic Heavy-Duty Flange-Type Honing-Tool for 10 to 12-In.-Diameter Bores

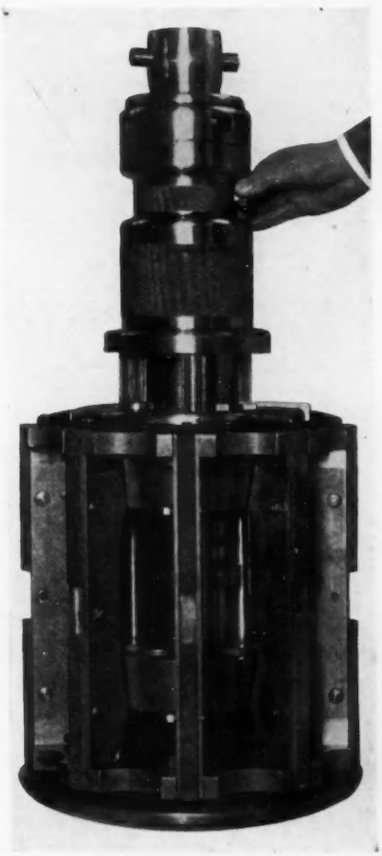


Fig. 14—Semi-Automatic Heavy-Duty Non-Compensating Honing-Tool

an inch but it also produces a profile curve at practically any magnification desired[2]. The principle embodies the idea of accurately recording the deflections of a light beam, and the magnifications are controlled by the length of the projection which is reflected through a series of mirrors positioned within the light-proof case which encloses the instrument. Sensitized photographic paper is contained on a drum or cylinder located within the square box-like housing shown in the center of the assembly.

As will be seen in Fig. 2, the light beam is deflected by the small mirror, which is assembled on the end of a small rocker arm having on its downwardly projected end a small diamond tracer point. As the specimen is actuated or passed under this diamond point, the light beam is deflected in exact relation to the surface roughness. This beam is projected on the sensitized paper, making a photographically produced curve of the profile from the specimen.

The development of the profilograph is really quite a contribution to the scientific art, as it will actually repeat readings measurable in millionths of an inch. As shown in Fig. 3, the diamond point is magnified exactly 1000 times for the purpose of comparing it with the specimen reading shown at the top, also magnified 1000 times vertically and 1000 times horizontally. It is obvious that it is within the accomplishment of the instrument to propel or actuate this point over the surface of the specimen in such a manner as to have the point exactly follow the contour of the minute surface. For practical purposes, as is shown in the second and third curves, horizontal readings are taken with a less number of magnifications than the vertical readings. By comparing results of various specimens recorded at the same magnifications in both directions, we have an exact knowledge of the surface texture and all arguments as to how rough is smooth are entirely obviated.

Fig. 4 shows the relative results representing the mean average condition as found on automobile cylinders and, for the purpose of comparison, microphotographs are shown on the left side, while the profilograph curves are reproduced on the right. The microphotograph of the reamed surface at the top was taken at 14 magnifications, whereas the comparable profilograph reading was taken at 30 magnifications horizontally and 2000 magnifications vertically. The center reading is of a micromatic rough-honed surface, the microphotograph being at 40 magnifications whereas the profilograph reading is 30 times horizontally and 2000 times vertically. The lower record is of the micromatic mirror-finish result, the magnifications being exactly comparable to the records shown for rough honing; and it is interesting to note that, by the two honing operations, all of the reamer marks have been eliminated and the surface has been freely cut down to base metal.

Some time ago it was contended that smooth cylinders prolong the breaking-in period of new engines. However, in the case of at least one Diesel-engine manufacturer, com-

[2] See *Mechanical Engineering*, September, 1933; Specifying Surface Quality, by E. J. Abbott and F. A. Firestone.

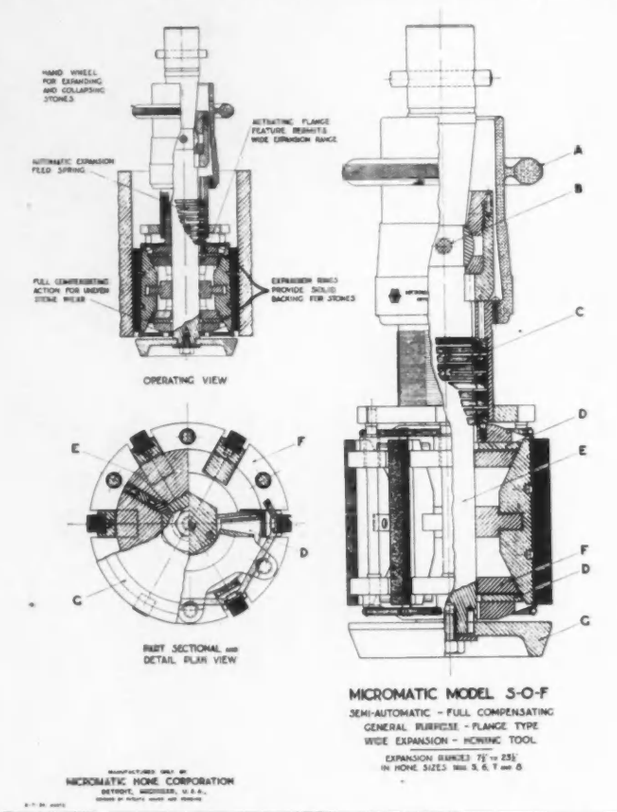


Fig. 15—Full-Compensating Adjustable-Flange-Type Semi-Automatic Honing-Tool with Wide Expansion Range

parative tests revealed that engines with honed cylinders came up to compression in 45 hr. of running; whereas, with the previously used reamed finish, 200 hr. of breaking-in time was required. At the same time, the cylinder-wall wear was reduced from 0.00075 in. in 24 hr. and 0.0015 in. in 50 hr. to no indicated wear in the same period of operation when using honed cylinder barrels.

A few years ago some of the present existing problems

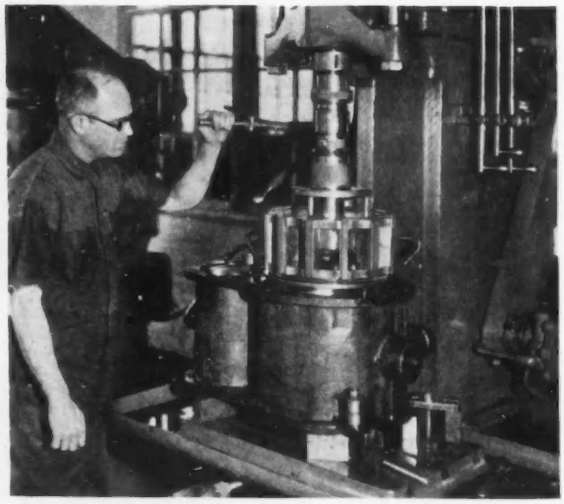


Fig. 16—Honing Railway Cross-Compound Compressor-Cylinders

with automobile engines, particularly as concerns oil consumption, were not so prevalent. However, with the increase in operating speeds, many new difficulties have been presented. The more extensive application of Diesel engines to automotive power is increasing the operating speeds of this type to the point where some of the same characteristics are effected as experienced with automobile engines. For this reason, I shall relate briefly the results of development work recently carried on as a matter of service to the automobile manufacturers. It is not extravagant to speculate that some of the same advantages incorporated in these recent developments could be made available for the larger oil-burning power-units.

The old adage that a rough cylinder-wall surface is required to hold the oil film has been entirely exploded. In fact, the oil consumption is much more accurately and effi-

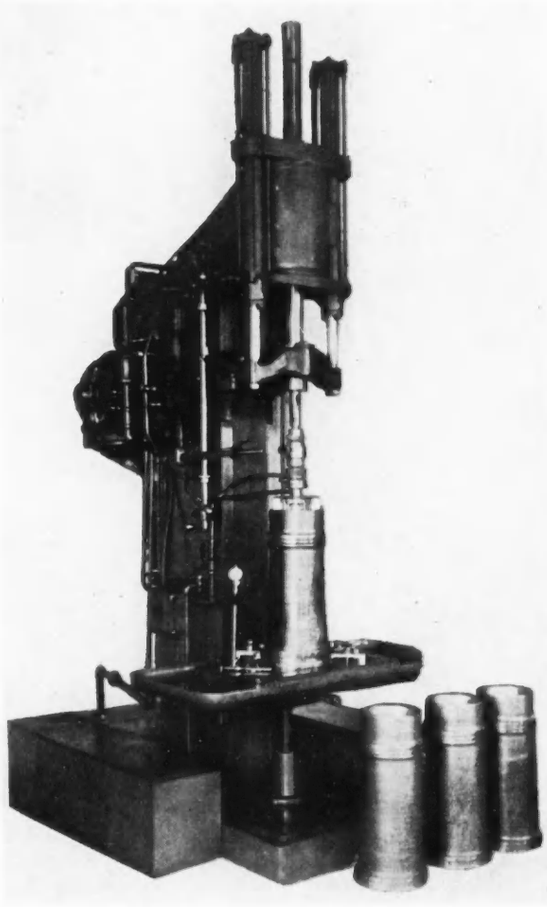


Fig. 17—Single-Spindle Hydraulic Machine for Heavy Duty

ciently controlled by the newer-type piston-rings, wiping the oil off *evenly* from a smooth cylinder-wall surface much in the same manner as windshield wipers wipe the rain from the smooth glass as compared with the effect of the rubber passing over a rougher surface when the shield is coated with ice.

It is interesting to know that all of the American motor-car manufacturers use the honing process as the final finishing operation for their cylinder bores, and that 66 per cent of the engines built in this country are mirror-finish honed in a secondary operation. Due to the fact that the automobile

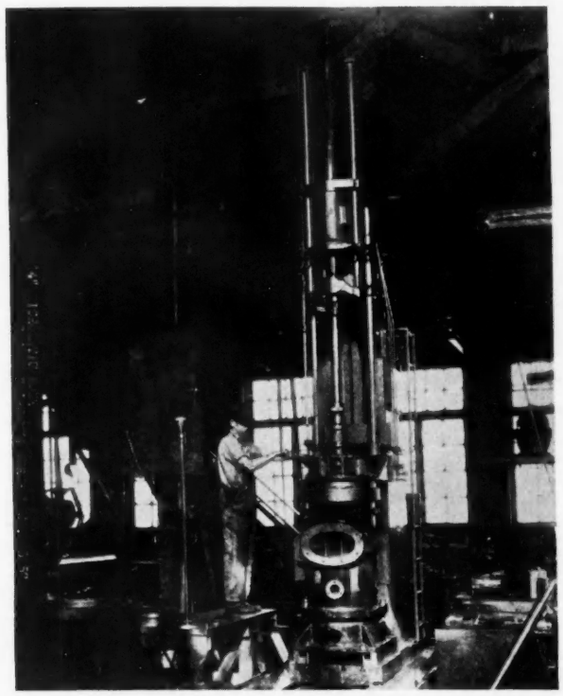


Fig. 18—Honing a Large Diesel-Engine Cylinder on a Semi-Automatic Hydraulic Machine

business is so highly competitive, it is obvious that the industry would not have expended the hundreds of thousands of dollars required for mirror-finishing equipment were it not definitely proved to be a decided necessity. Incidentally, it is just one of those things which does not stick out as a polished gadget to appeal to the feminine buyers. Possibly, if this were the case, it would have met with less resistance when it was introduced to the manufacturers. In fact, a great many dynamometer tests have been made. In one case, directly under the author's observation, a total of 18 engines were run, 9 with single-honed cylinders and 9 others with a secondary mirror honed-finish, showing an average improvement in favor of the higher finish of 32 per cent in oil consumption, while operating under full load at 3000 r.p.m.

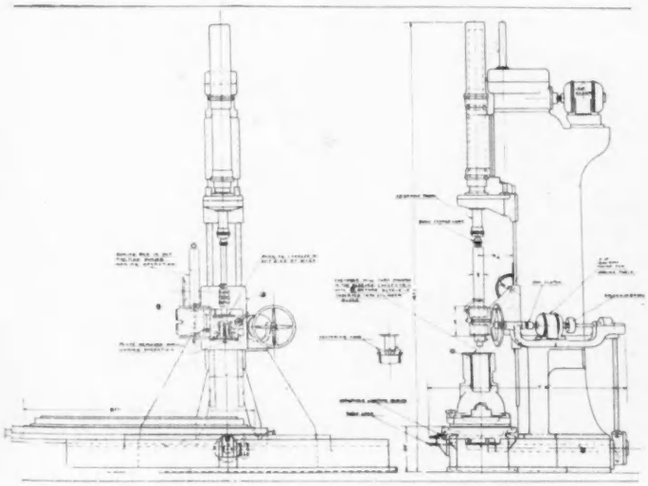


Fig. 19—Combination Boring and Honing Machine

Honing Engine-Cylinder Bores

In automobile production the cylinder blocks are universally honed on multiple-spindle machines with full-automatic tool-equipment as shown in Fig. 5. In this particular installation, one man operates two machines at a rate of 70 to 90 blocks per hr., removing 0.0025 to 0.0030 in. of stock in the rough-honing operation and from 0.0005 to 0.0007 in. in the mirror-finishing secondary-operation, while developing accuracy within limits from 0.0005 to 0.0007 in. for roundness and straightness.

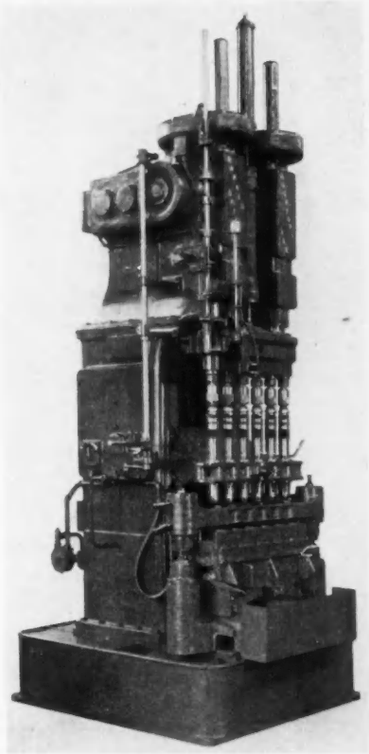


Fig. 21—Multiple-Spindle Honing-Machine for Truck and Bus-Engine Sleeves

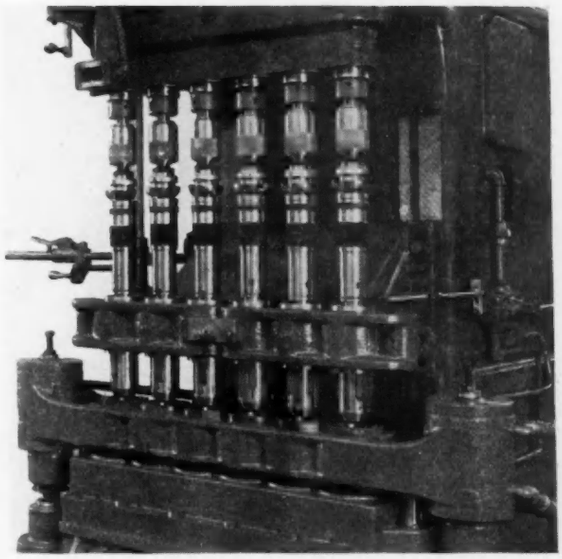


Fig. 20—Honing Tools and Fixture for the Automatic Honing of Cylinder Sleeves

The full-automatic-type honing-tool shown in Fig. 6 is most commonly used in the automobile industry for cylinder-bore honing. As shown in Fig. 7, the three-finger construction in the honing-tool-head mechanism, as well as the bar-type feed-spring *D* in the center of the tool, automatically controls the pressure of the abrasive members against the cylinder walls during the entire cycle of operation. The single-cone, *G*, principle of expansion comprised in the body of the tool permits a rocking or tilting action to the abrasive holders so as to compensate for uneven stone-wear.

Fig. 8 shows a close-up of the six-spindle installation. Of especial interest is the tunnel-type fixture supporting the operating bushings which serve the purpose of actuating the automatic tool. Fig. 9 shows another close-up view of a full-automatic installation on the rough-honing operation of the V-type automobile-engine block. The fixture is of an interesting design, hydraulically controlled to index from one bank of cylinders to the other. Fig. 10 shows the entire vertical machine and fixture assembly which is only one of a large number used by one of the American motor-car manufacturers.

A new angle-type honing-machine, shown in Fig. 11, is built to actuate the full-automatic tools in the honing of a

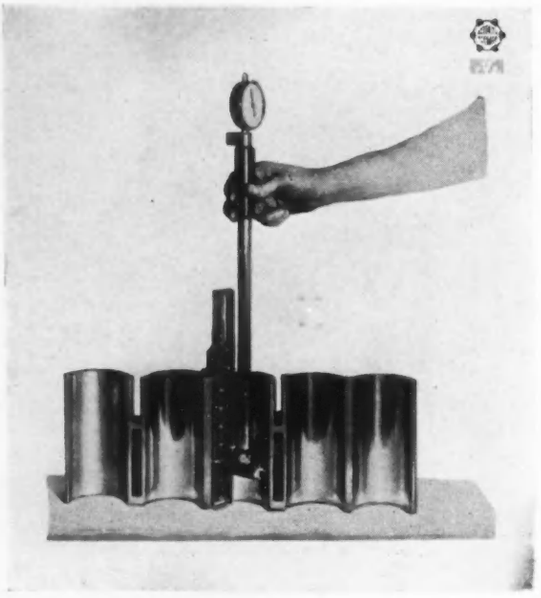


Fig. 22—A Dial Gage and Its Locating Fixture

Fig. 23—A Cylinder Block and An Hydraulic Wrench

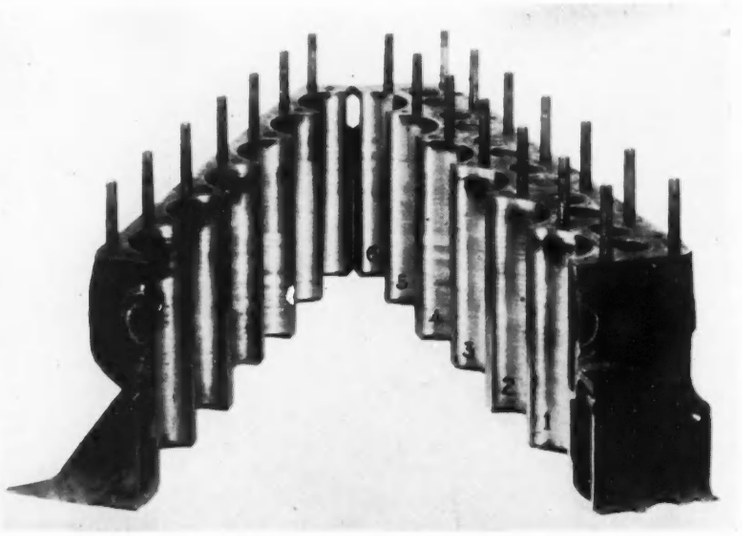


Fig. 24—A Cylinder Block Showing Distortion

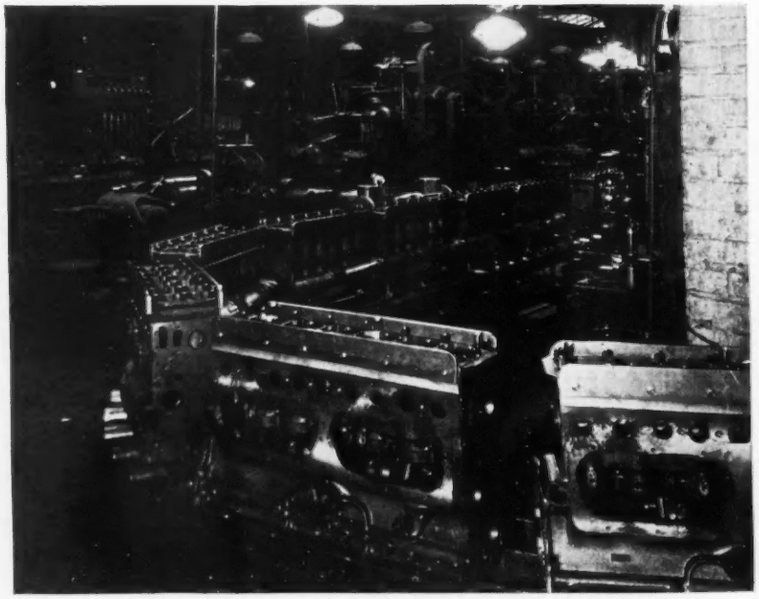


Fig. 25—Distortion Plates Are Used by One Manufacturer in Production

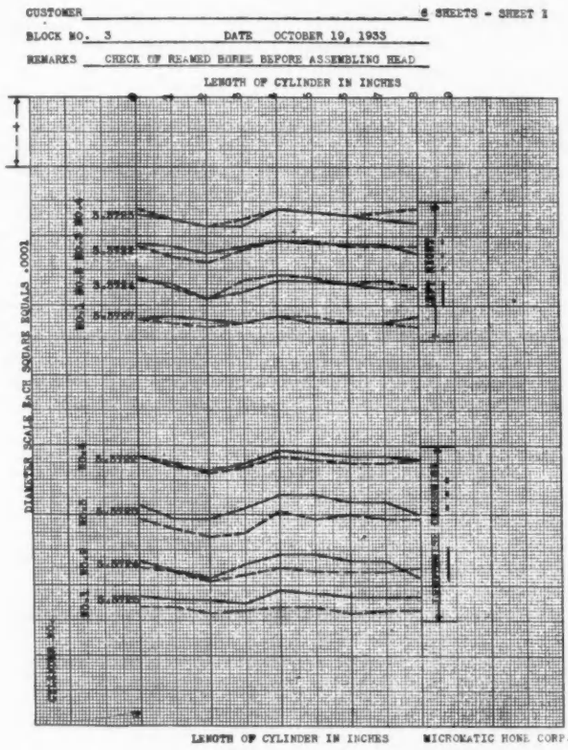

CUSTOMER
6 SHEETS - SHEET 1
BLOCK NO. 3
DATE OCTOBER 19, 1933
REMARKS CHECK OF REAMED BORES BEFORE ASSEMBLING HEAD
LENGTH OF CYLINDER IN INCHES
DIAMETER SCALE EACH SQUARE EQUALS .0001
LENGTH OF CYLINDER IN INCHES
MICROMATIC HONE CORP.

Fig. 26—Cylinder Shape after Reaming

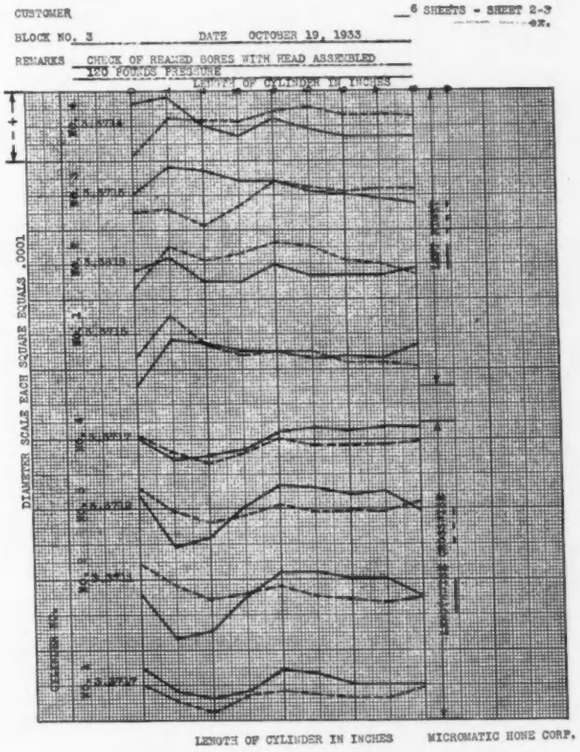

CUSTOMER
6 SHEETS - SHEET 2-3
BLOCK NO. 3
DATE OCTOBER 19, 1933
REMARKS CHECK OF REAMED BORES WITH HEAD ASSEMBLED
120 POUNDS PRESSURE
LENGTH OF CYLINDER IN INCHES
DIAMETER SCALE EACH SQUARE EQUALS .0001
LENGTH OF CYLINDER IN INCHES
MICROMATIC HONE CORP.

Fig. 27—Distortion Resulting from Drawing Down a Cylinder Head

V-type eight-cylinder engine-block, all barrels being honed simultaneously.

Among a great many satisfactory applications of the honing principle and of considerable interest is the honing of large Diesel-engine cylinders as well as cylinder-bore liners of the wet type for bus and tractor engines. The semi-automatic heavy-duty honing-tool shown in Fig. 12 is used to hone cylinders ranging from 8½ to 10 in. in diameter. The tool stands 34 in. high.

The tool shown in Fig. 13 is used for Diesel-engine bores ranging in diameter from 10 to 12 in. The stone holder and expansion-cone arrangement are of the non-compensating type to step across port openings or relieved sections in the cylinder walls. The tool shown in Fig. 14 is also the heavy-duty non-compensating type for honing Diesel-engine cylinders ranging in diameter from 14 to 18 in. The honing tool shown in Fig. 15 incorporates the semi-automatic feature *C* of feeding out the abrasive stones, while at the same time full compensation for uneven stone-wear is afforded; also, the tool has a wide expansion range to meet different diameter sizes. As may be seen, a very rigid construction is incorporated in the heavy-duty flange-type design.

Fig. 16 shows the honing of railway cross-compound compressor-cylinders with a special tool of the semi-automatic type built for the purpose. The heavy-duty hydraulic honing-machine of the single-spindle type is shown in Fig. 17 in operation on medium-size liners for relatively large engines. This type of equipment is suitable for quite a large range of sizes as the machine provides quick adjustment for variable-speed control. A 14-in. Diesel-engine cylinder is shown in the honing operation in Fig. 18, with a heavy-duty ratchet-type non-compensating honing-tool actuated by a large single-spindle machine of the vertical type which removes

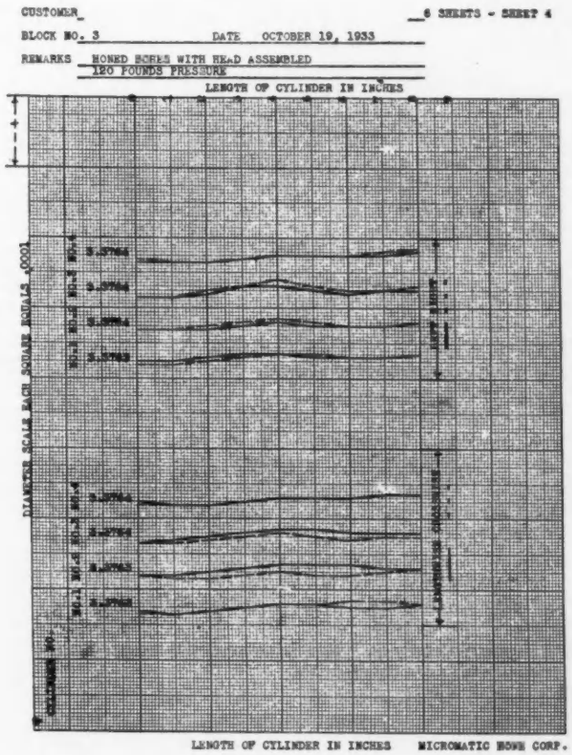

CUSTOMER
6 SHEETS - SHEET 4
BLOCK NO. 3
DATE OCTOBER 19, 1933
REMARKS HONED BORES WITH HEAD ASSEMBLED
120 POUNDS PRESSURE
LENGTH OF CYLINDER IN INCHES
DIAMETER SCALE EACH SQUARE EQUALS .0001
LENGTH OF CYLINDER IN INCHES
MICROMATIC HONE CORP.

Fig. 28—Correction of Error by Honing in the Presence of Head Strains

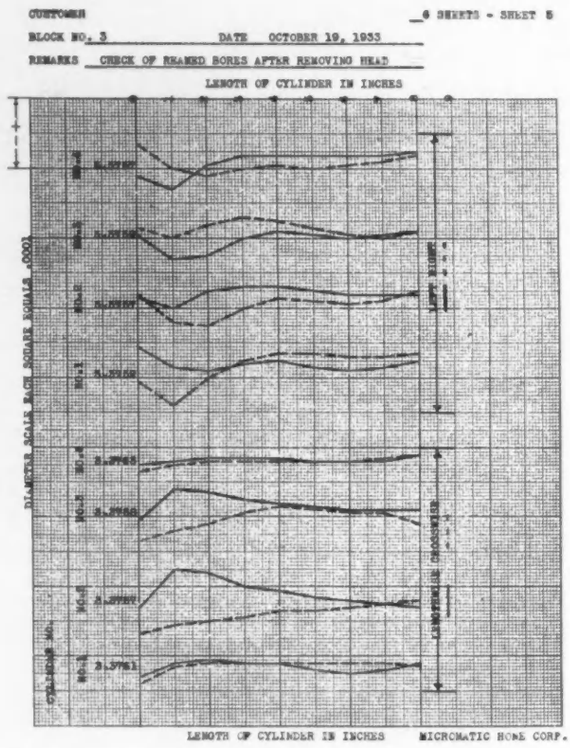

CUSTOMER
BLOCK NO. 3
DATE OCTOBER 19, 1933
REMARKS CHECK OF REAMED BORES AFTER REMOVING HEAD
LENGTH OF CYLINDER IN INCHES
LENGTH OF CYLINDER IN INCHES
MICROMATIC HONE CORP.

Fig. 29—Head Strains Relieved by Removing the Cylinder Head

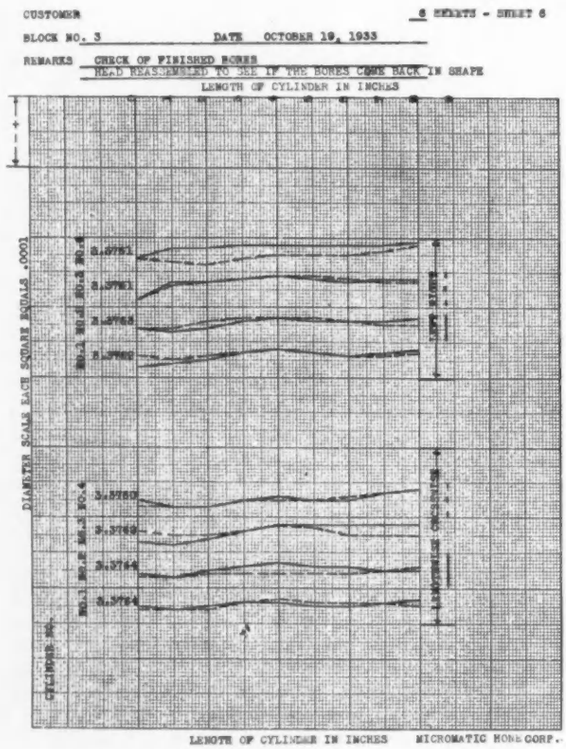

CUSTOMER
BLOCK NO. 3
DATE OCTOBER 19, 1933
REMARKS CHECK OF FINISHED BORES
HEAD REASSEMBLED TO SEE IF THE BORES COME BACK IN SHAPE
LENGTH OF CYLINDER IN INCHES
LENGTH OF CYLINDER IN INCHES
MICROMATIC HONE CORP.

Fig. 30—Shape of the Cylinders after Reassembling the Cylinder Head

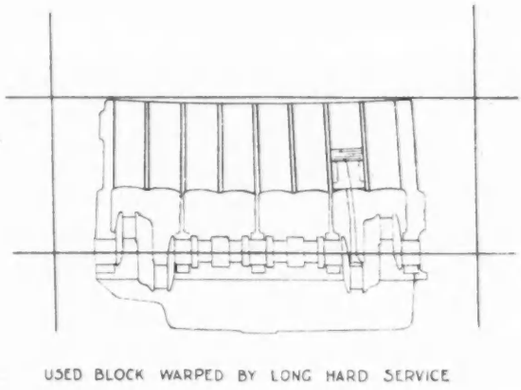


Fig. 31—Illustrating the Principle of a Warped Block

from 0.006 to 0.009 in. of stock in an actual honing period of 10 min.

The introduction of the larger type of multiple-cylinder Diesel-engine for locomotive use, as well as the maintenance of these engines, has necessitated the development of a combination boring and honing machine for cylinder liners, as shown in Fig. 19. Smaller liners, for truck and bus engines, are usually honed on multiple-spindle machines with full-automatic honing-tool equipment, as shown in Fig. 20. The fixtures are designed to incorporate the feature of loading and unloading by sliding the work-holding carriage forward and back. It is not uncommon for machines of this type to be equipped with rough-honing tools on three of the spindles, with the remaining three spindles equipped with mirror-finishing hones, both of the full-automatic-type construction. In cases of this kind, the operating bushings are separated

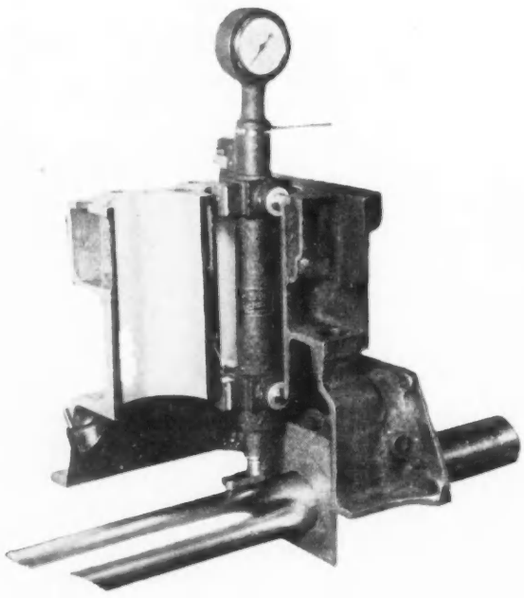


Fig. 32—Method of Measuring Squareness

from the guiding bushings as shown also in Fig. 20. The entire machine, including tools and fixture for the large-scale production of truck and bus-engine sleeves, is shown in Fig. 21.

Distortion of Cylinders

Due to the fact that it is utterly impossible for a piston ring to follow an out-of-round contour, especially if the error is in the form of a pocket, there is a *direct relation* of cylinder-wall *finish* and *accuracy* to engine performance. In fact, when the mirror finish was first offered to the motor-car manufacturers, some of the preliminary tests showed a higher oil-consumption when the mirror finish was incorporated. In each case, however, these same engines were not particularly good performers, irrespective of the finish used, and a careful check through production procedure very clearly showed that the cylinder barrels were *distorted* as a result of various engine-assembly operations, especially when the cylinder heads were drawn down.

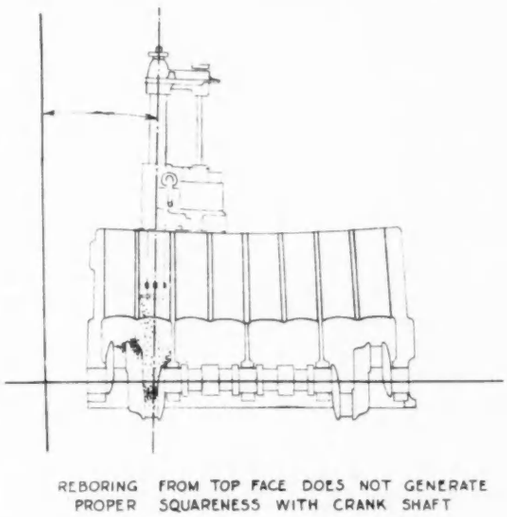


Fig. 33—Boring from the Top Face of a Warped Block

As shown in Figs. 22 and 23, various instruments were used for measuring the most important characteristics. Fig. 22 shows the device which was used for positioning the anvil of the indicator so that a number of readings could be taken before and after assembly operations. From the data thus secured, charts were plotted to study the inherent cylinder shapes. Of especial interest is the hydraulic wrench shown in Fig. 23, which made it possible to set up strains of known amounts. The cylinder heads were bored out to permit indicator readings down through the top and also to permit the blocks to be honed while the head strains were set up.

There was a more or less popular claim that most of the cylinder distortion is due to the effects of heat encountered while the engine is in operation. This, no doubt, is a factor; however, it has been proved that it is by far the lesser of the causes in the case of automobile engines. The telltale of distortion is the black or dark-brown spots which are commonly visible on the cylinder walls and that usually are found opposite the head studs. A very interesting illustration of

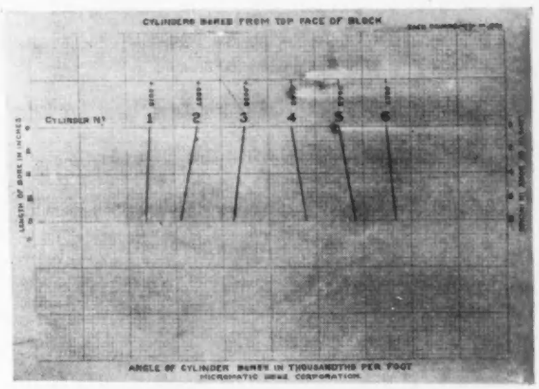


Fig. 34—Chart Showing Resulting Misalignment

one test which is, in itself, good proof, is given in Fig. 24. The block has been cut open after producing the result, for examination. The spots were produced under cold conditions, instead of hot, to prove that their cause does not result from heat. Bores Nos. 1, 2 and 3, were rebored from the top face of the block without any head strains, and then the walls were coated with a Prussian-blue solution. After this, a special Aline-O-Plate was drawn down with a HydrO-Wrench, setting up the cylinder-head strains. While in the position of this assembly, a honing tool was passed over the surface for only a few strokes, cutting off the high places. The blue was left undisturbed in the pockets, as shown by the dark spots in the illustration. These spots are exactly the same shape and size as those resulting from normal operation of an engine of the same model. To prove the point further, cylinders Nos. 4, 5 and 6 of the same block were first rebored from the Aline-O-Plate in the presence of the distortion strains, and coated with the Prussian-blue solution before relieving the strains and honing the surface. This exactly reverses the procedure carried out in the first test. It will be noticed that where the dark spots are positioned on cylinders

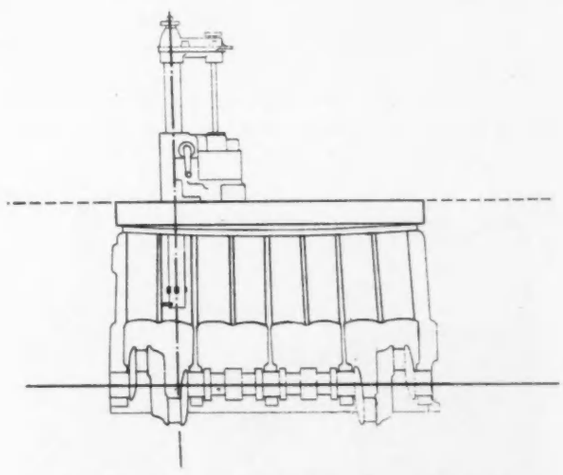

MICROMATIC ALINE-O-PLATE COMPENSATES FOR
WARPED CONDITION AND ASSURES SQUARENESS WITH
CRANK SHAFT AND PROPER ALIGNMENT OF CYLINDERS

Fig. 35—Illustrating a Principle of Boring from an Aline-O-Plate

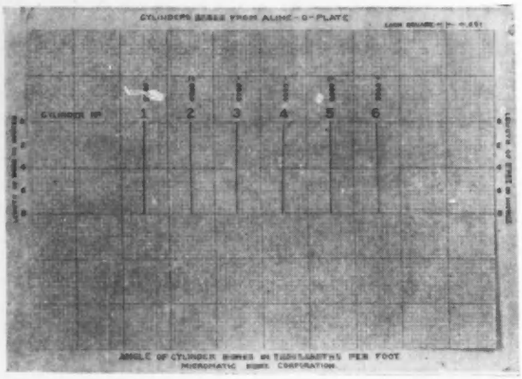


Fig. 36—Chart Showing Resulting Good Alignment

Nos. 1, 2 and 3, we have light spots on cylinders Nos. 4, 5 and 6, and vice versa. The results thus shown are very consistent with the results obtained by measuring the distortion as well as consistent with the evidence to be seen as a result of actual operation in service. Therefore, it is concluded that head strains are more serious as a factor contributing to distortion than is heat.

The production view, Fig. 25, shows what at least one manufacturer is now doing to compensate for cylinder distortion which results from head strains. Distortion heads to the number of 250 have been provided for use in production. They are assembled before honing and removed afterward. It is interesting to know that, on one particular engine, the oil consumption was varied from 650 to 1500 miles per gal. by simply drawing down the cylinder-head nuts from 125 lb. to 150 lb. with the hydraulic wrench.

To permit a study of the inherent shapes resulting from distortion, charts were plotted of one particular block, as shown in Figs. 26 to 30. The heavier vertical lines represent 0.001 in. and the finer graduations 0.0001 in. The heavier horizontal lines denote inches in length of the cylinders. Dotted lines are used to represent diameter readings across the bores in one direction, and solid lines are used to record the measurements taken at 90 deg. from the first. Therefore, the difference between the two lines exemplifies the shape of the cylinders.

Fig. 26 shows the way the cylinders were machined by the reaming operation. Fig. 27 shows distortion as a result of pulling down the cylinder-head nuts with the hydraulic wrench. Fig. 28 shows how the error was corrected by honing while the head strains were set up. Fig. 29 shows the result of what happened when the strains were relieved by removing the cylinder head. Fig. 30 is from a reading taken after remounting the head and shows that the cylinders can be brought back into proper shape by using the hydraulic wrench for the final assembly of the standard head.

Experience has indicated that, with L-head engines, the cylinder distortion results from local strains in the vicinity where the stud anchors are located. It is significant that, in most cases, with overhead-valve engines, the distortion due to head strains is less, and it is concluded that the replaceable wet-sleeve-type construction lends itself to greater possibilities in preventing cylinder-barrel distortion. In the case of high-speed Diesel-engines where the compression ratios are considerably higher, it would seem that the cylinder-liner type of construction would be almost requisite.

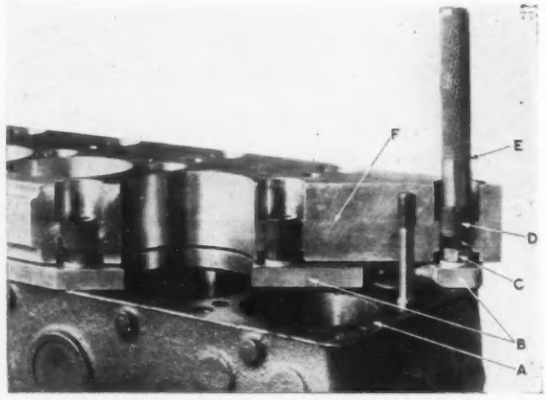
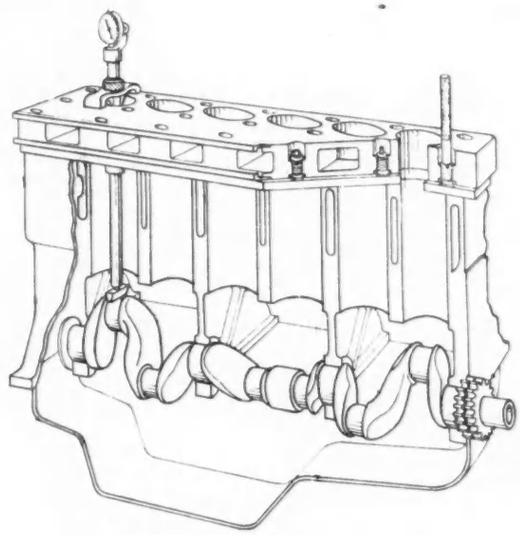


Fig. 37—Cutaway View of an Aline-O-Plate



MICROMATIC ALINEOPLATE Set Up With ALINEOGAGE

Fig. 38—Showing the Use of the Aline-O-Gage in Adjusting the Aline-O-Plate Parallel to the Crankshaft

Service Equipment Influence on Cylinder-Block Design

Probably, the high cost of production of the replaceable wet-sleeve-type cylinder-block has prevented a wider use of this construction in automotive engines. This higher cost may now be justified and this kind of construction more universally used as the increase in operating speeds has set up the new requirement for round cylinders; at the same time, the replaceable sleeves facilitate reconditioning in the service field. However, for the first time, and only recently, has it been possible to recondition cylinder bores of the cast-in-block type, using portable equipment, within standard factory limits for alignment and finish. The fact that this can now be done will undoubtedly influence engine design to the effect that the cast-in-block type will remain in extensive use. From this

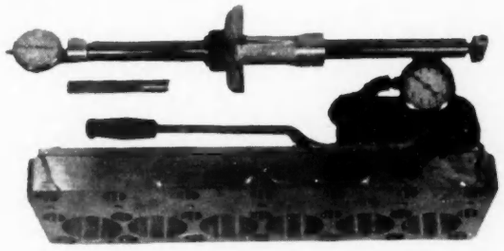


Fig. 39—Aline-O-Plate Equipment

point of view, it is interesting to give consideration to a new method of engine rebuilding.

It is obvious, from the outline already given, that the following factors of accomplishment should be incorporated in satisfactory engine-rebuilding equipment.

(1) Produce the real mirror finish
(2) Assure squareness with the crankshaft
(3) Compensate for cylinder distortion
(4) Dispense with the necessity for removing the engine from the chassis
(5) Remove all chips from boring as well as the grit from honing
(6) Eliminate the crankcase clean-up operation

So far as the engine itself is concerned, the condition to be contended with, which is not related to new engines under production conditions, is the warpage of the blocks due to aging in service. In fact, it is for this reason impractical to rebore used engine-blocks by locating from the original pan rail, as done in production, unless in each case the main bearings are rebored from the same location. Neither is it entirely reliable to rebore from the top face, notwithstanding that it does not warp as much as the pan rail. Again, there is no assurance that the top face has been milled off exactly parallel with the crankshaft; therefore, in addition to features already enumerated, compensation for warpage should be provided.

The cartoon, Fig. 31, illustrates warpage. Fig. 32 shows the instrument used to check squareness of the cylinder with the crankshaft. Obviously, we cannot expect to generate proper alignment by reboring from the top face if it is warped or out of parallel, as is shown, exaggerated, in Fig. 33. Fig. 34 shows the ill-effects of this condition on one particular block. The length of the curves represents the length of the cylinder bores, and each of the finer squares in the horizontal direction is equal to 0.001 in. It can be seen that, in this case, the error on No. 2 cylinder in particular is over 0.0055 in. out of square, which is almost double the maximum tolerance allowable in production.

The new method of regenerating alignment overcomes obstacles existing in the past, one unit of which is termed the Aline-O-Plate. This is indicated in Fig. 35, to illustrate the principle of generating proper alignment with the crankshaft. Fig. 36 shows the results obtained on the same block when the proper method of obtaining alignment was used.

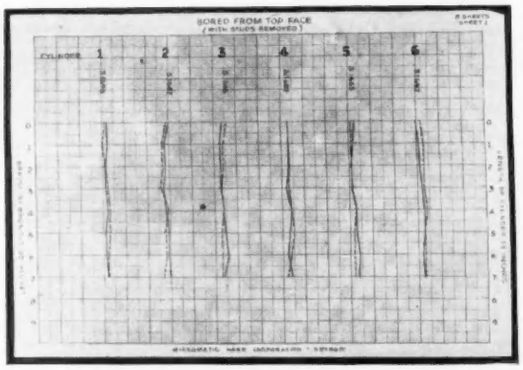


Fig. 40—Bored from the Top Face

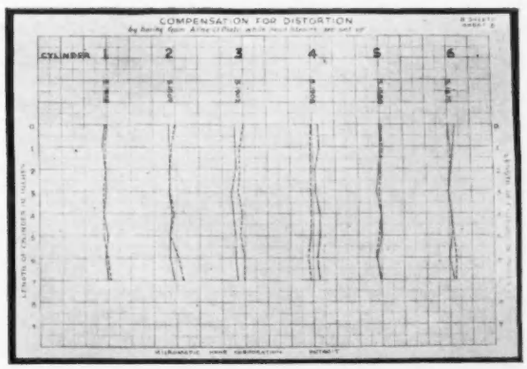


Fig. 42—Compensation for Distortion by Boring from Aline-O-Plate with Head Strains Set Up

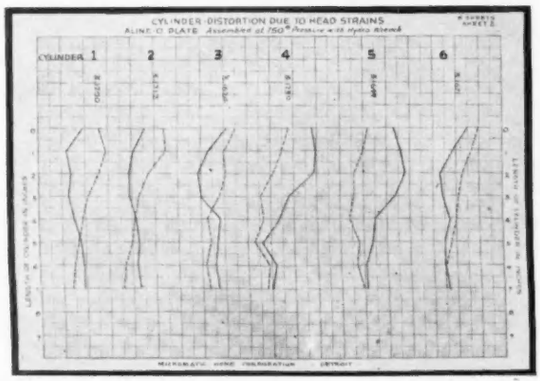


Fig. 41—Cylinder Distortion Due to Head Strains

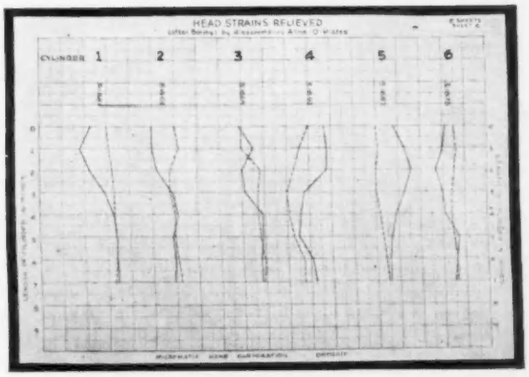


Fig. 43—Head Strains Relieved

This new method of engine rebuilding entails an entirely different procedure than has been common practice in the past. The fundamental principle employed is to machine the cylinder bore in relation to the crankshaft alignment, irrespective of the shape of the cylinder block. If the crankshaft and main bearings need reconditioning, this should be the first operation under the new process as the new equipment offered now makes it possible to bore from the Aline-O-Plate, after it has been set up, exactly square with the crankshaft.

As shown in Fig. 37, the gasket *A* is first placed on top of the block and then the relatively thin distortion plate, *B*, is assembled. Spherical-headed cap-screws *C* are then drawn down to a uniform tension, using the HydrO-Wrench. This sets up the same head-strain distortion as effected when the standard cylinder head is later drawn down with the HydrO-Wrench at the same reading. The Aline-O-Plate *F* is next placed in position on top of the distortion plate *B*, and threaded bushings *D* are provided to effect the adjustment of the Aline-O-Plate. The threaded bushings are machined with a radius on the lower end so as to seat themselves properly on the spherical-headed cap-screws, at *C*. Adjustment is effected with the special adjustment-wrench *E*.

Fig. 38 shows how the Aline-O-Plate is adjusted to be exactly parallel with the crankshaft by using the Aline-O-Gage depth-indicator to take a reading from each end-crank-throw journal to the top face of the Aline-O-Plate. The threaded bushings, as previously explained, are adjusted until a zero reading is obtained with the Aline-O-Gage from each end-crank-throw pin in such a manner as to assure that the Aline-O-Plate is exactly parallel with the center line of the crankshaft.

The Aline-O-Plate equipment, shown in Fig. 39, enables an operator to recondition the cylinders of an engine to within the exacting limits of tolerance specified in standard production-procedure. As shown, the equipment provides a means for proper alignment of the cylinders so that they are square with the center line of the crankshaft, the boring operation regenerates this alignment irrespective of warpage of the cylinder block, and the distortion plate holds the cylinders in the same distortion as when the cylinder head is drawn down. Thus, two things are accomplished in the one operation: correction of misalignment and compensation for distortion due to head strains. The series of charts that follows shows the effects of distortion as well as its correction by the use of this new equipment. The scale is the same as previously shown for production conditions.

Fig. 40 shows the measurements of cylinders when bored from the top face with cylinder-head studs removed. This is the current boring operation as generally practiced when bored from the top face of the cylinder block without regard for distortion. Fig. 41 shows the measurements of the cylinders after the distortion plate was drawn down with the HydrO-Wrench at 150-lb. pressure, and shows the cylinder distortion, due to head strains, that would exist in the cylinder block after the cylinder head is drawn down under the old method of assembly.

Fig. 42 shows the measurements of the cylinders after boring from the Aline-O-Plate while head strains are set up in the cylinder by the distortion plate having been drawn down

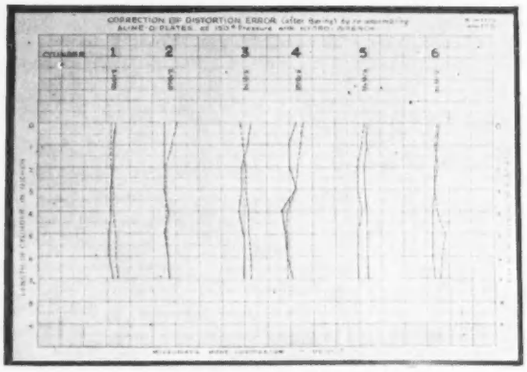


Fig. 44—Correction of Distortion Error

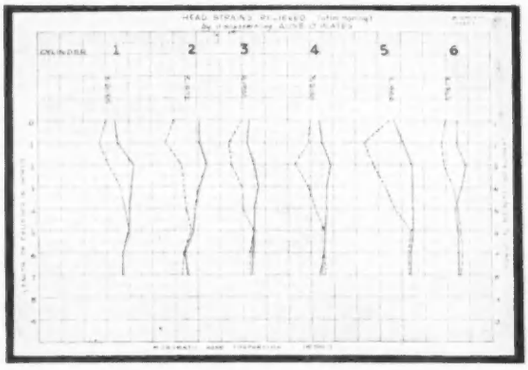


Fig. 46—Head Strains Relieved

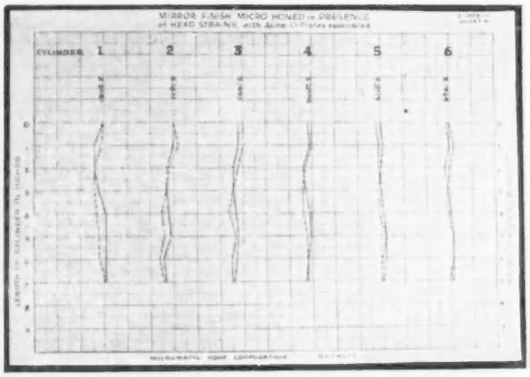


Fig. 45—Mirror-Finish Micro-Honed in the Presence of Head Strains, with Aline-O-Plate Assembled

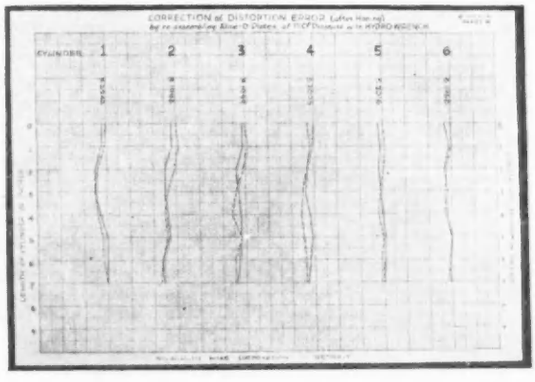


Fig. 47—Correction of Distortion Error

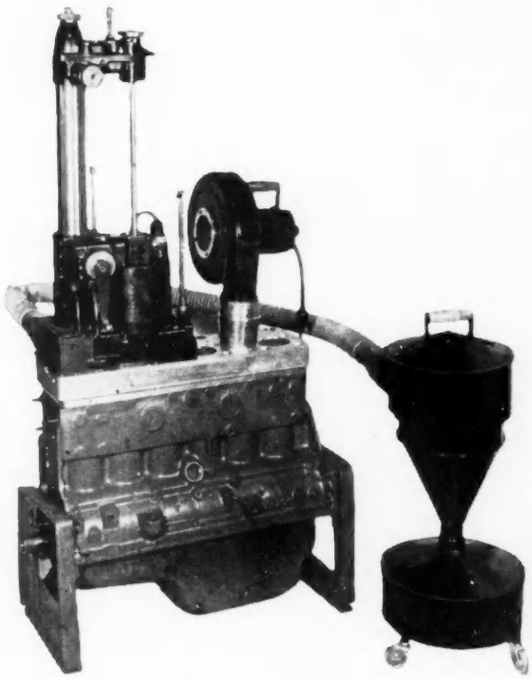
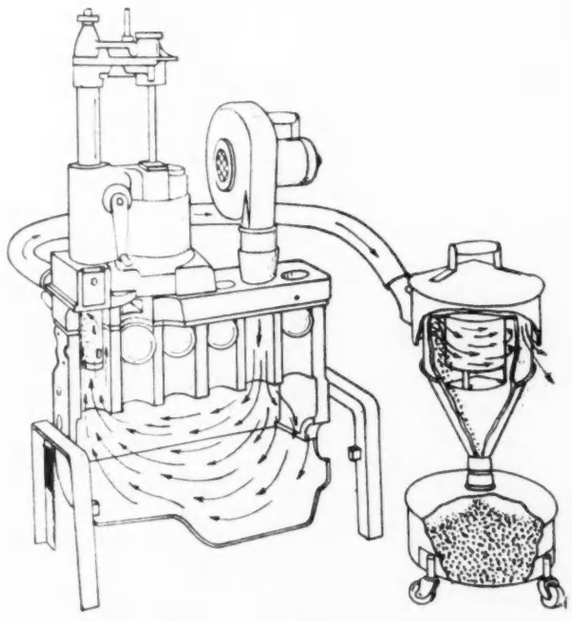


Fig. 48—Rid-O-Grit Equipment in Use During the Boring Operation



MICROMATIC ALINEOPLATE and RIDOCRIT
Set Up for Reboring Operation

Fig. 49—Illustration of a Boring Operation

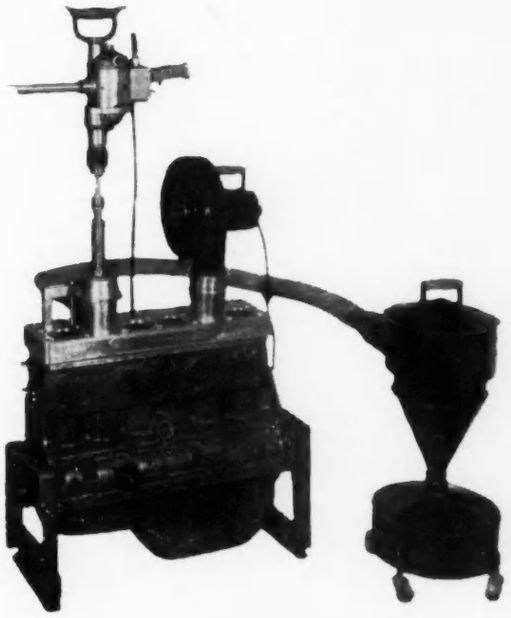


Fig. 50—Use of the Rid-O-Grit During the Honing Operation

with the HydrO-Wrench. Fig. 43 shows the measurements of the cylinders after the head strains had been relieved by disassembling the Aline-O-Plate and distortion plate after the boring operation. It will be noted that the cylinders go out-of-round when the head strains are relieved.

Fig. 44 shows the measurements of the cylinders by reassembling the distortion plate and Aline-O-Plate at 150-lb. pressure with the HydrO-Wrench. It will be noted that the cylinders were brought back to roundness again when the same strains were set up. Fig. 45 shows the measurements of the cylinders after the mirror finish was applied in the presence of head strains in the cylinder block.

Fig. 46 shows the measurements of the cylinders after head strains were relieved by disassembling the Aline-O-Plate and distortion plate after the honing operation, and here again it will be noted that the cylinders go out-of-round after the head strains have been relieved. Fig. 47 shows that the cylinders can be brought back into proper roundness by reassembling the Aline-O-Plate and distortion plate at the same 150-lb. pressure with the HydrO-Wrench as used throughout the test. This is a typical condition of the cylinders after the standard cylinder-head is drawn down with the same 150-lb. pressure, as measured with the HydrO-Wrench.

A Method That Keeps Grit and Chips Out of the Crankcase.—The next step, and one that is not encountered in building new engines, is the necessity for keeping them clean during the machining operations. This is of major importance in the service field, and this development represents a new patented method which is quite a contribution to the industry. The equipment, as shown in Figs. 48 and 49, is known as the Rid-O-Grit and operates on the pressure principle of blowing out the grit and chips. After removing the pistons and connecting rods, the oil pan is reassembled with three or four cap screws to enclose the bottom of the engine,

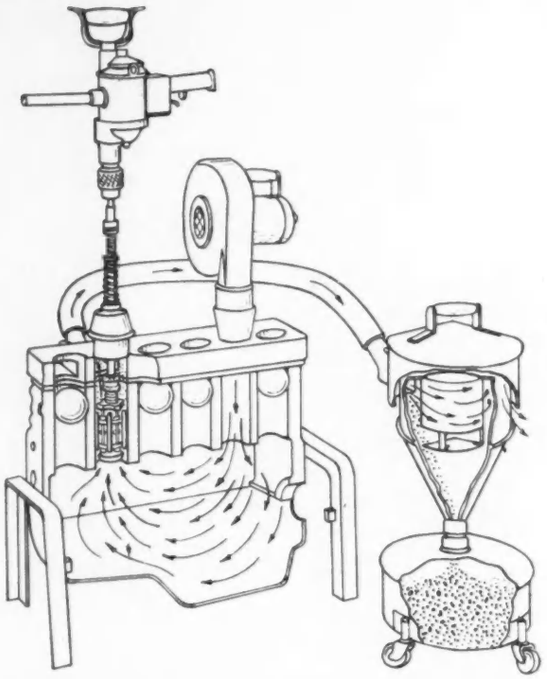


Fig. 51—Illustration of a Honing Operation

and then all of the cylinder bores not being used are plugged up at the top with rubber adapters. An especially designed powerful blower pumps clean air down one of the cylinders at a velocity of 120 m.p.h. so as to create a pressure in the crankcase. It is obvious that this method provides a constant or continuous stream of air coming up the open cylinder during the time the tool is being adjusted; in fact, while any work is being done around the bore opening. This prevents anything from falling down at any time. The boring bar is fitted with an adapter to close the cylinder being worked on, except for an exhaust outlet for the airstream. It is apparent that none of the chips can fall down against the flow of air. The chips are collected in a cyclone-type chip-arrester, as shown. This differs from the usual cloth-bag-type arrangement, as the cyclone-type chip-arrester does not become clogged and offers no resistance to the airflow. Another feature of advantage is that the grit does not pass through the blower unit.

This same equipment is also used for the MicrO-Honing operation, as shown in Figs. 50 and 51. The Rid-O-Grit device is over 98 per cent efficient on any size of cylinder bore, and may be relied upon to the extent of eliminating the crankcase clean-up operation entirely after either boring or honing. To counterbalance the weight of the hone and electric drill, a spring is assembled on the bell-cap driver. A *C*-nut stop-ring is adjustable to control the length of the stroke. Three different sized adapters are furnished to reach all the passenger-car bore-ranges and the hose outlets are interchangeable to fit all units. When it is necessary to recondition one or two slightly scored cylinders, the use of the Aline-O-Plate and the Distortion Plate may not be necessary, and any or all of the equipment may be used with or without the Aline-O-Plates for boring or honing. Fig. 52 shows the Rid-O-Grit set-up, for honing with the studs in place and without the Distortion Plate and the Aline-O-Plate.

Cylinder-Finish Service-Field

It is now possible to get the real Micromatic mirror finish with a portable tool known as the MicrO-Hone, shown in Fig. 53. The MicrO-Hone, like Micromatic production hones, has been built to produce the most perfect cylinder possible. The tool is of a higher grade than has heretofore been offered to the service field. It comprises many of the features incorporated in the heavy-duty full-automatic tools used in production. Unlike any other service hone, the stones are diametrically opposite each other and exactly on the center of the tool. Four stones are used, and each stone contains a felt wick running the full length of the stone. MicrO-Honing is a semi-wet operation. The stone wicks are saturated before each honing operation with a specially developed cutting fluid known as LubrO-Cant, which constantly cleanses the pores of the stones, prevents them from clogging, and enables the sharp cutting edges of the stones to cut to base metal without burnishing.

Several unique features of the MicrO-Hone explain its method of producing round, straight holes, and its fast-cutting action to base metal. In Fig. 54, the MicrO-Hone is shown as a part of the assembly for use with the Rid-O-Grit. Letter *A*, of Fig. 54, refers to the *C*-nut stop-ring on bell-cap driver which provides an adjustment to control the length of the stroke of the hone in the cylinder. Letter *B* refers to the ball-bearing ring which assures smooth operation to prevent spring-assembly parts from rotating. Letter *C* refers to the double-coil springs which counterbalance the weight of

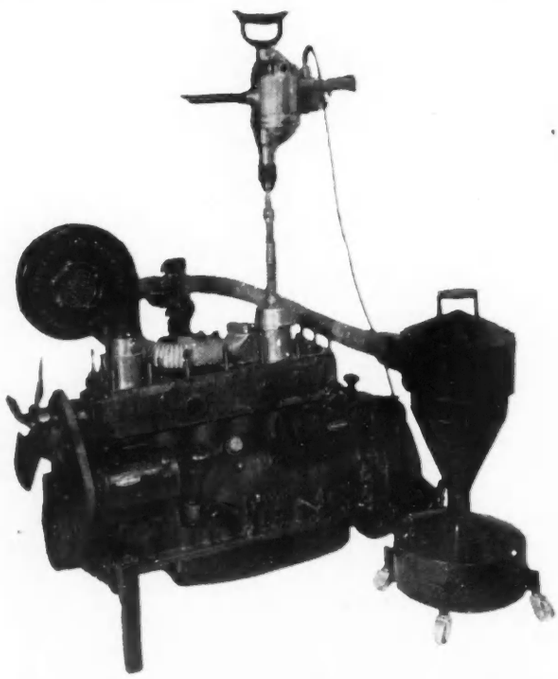


Fig. 52—The Rid-O-Grit Equipment Can Be Used without the Distortion and Aline-O-Plate

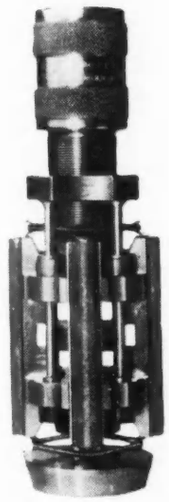


Fig. 53—The Mirror-Finish MicrO-Hone

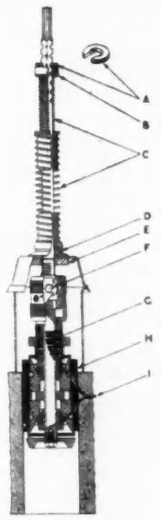


Fig. 54—Features of Design and Construction of the MicrO-Hone

the electric drill and the MicrO-Hone. Letter *D* indicates the universal ball-and-slide joint, and this feature provides a floating action to permit the driver to work at an angle. Letter *E* refers to the stop collar which limits the upper end of the stroke. Letter *F* indicates the bayonet-lock ball-joint assuring smooth universal action and which facilitates the ease of connecting and disconnecting the driver from the tool. Letter *G* points to the automatic feed-mechanism which assures that the abrasive members are held at a uniform pressure against the cylinder wall. This gives a constant cutting action. Letter *H* refers to a feature common to both production and the field-service hones; like all Micromatic production hones, the MicrO-Hone allows for uneven stone-wear. Note that the stones are tapered, while the cutting face is parallel with the cylinder walls. Letter *I* refers to the expansion rings which provide a solid backing for the abrasive stones. This feature entirely eliminates chatter.

The angle of the stone holders, resting upon the expansion rings, is beyond the angle of reversibility. This is the principle of a wedge which cannot be forced out of position regardless of the pressure on the sides. Flange-type construction, a feature of the Micromatic production hones, is also a feature of the MicrO-Hone. These flanges are shown between the stone holders of Fig. 53, and provide a rigid support for the side of the stone holders; holding the stones rigidly in their exact position, and eliminating chatter. The tool is easily driven by any ⅜-in. or heavy-duty ½-in. electric drill, and the MicrO-Hone produces the real mirror finish while actually cutting down to base metal in one operation. The genuine mirror finish is applied to a bored hole in one operation, removing up to 0.0015 in. of stock on the diameter in 3 min. to a base-metal surface. Profilograph records have been made of cylinder surfaces produced by conventional methods of cylinder reconditioning. The principle of the profilograph was illustrated in Fig. 1.

The five profilograph records in Fig. 55 show first, in Graph 1, a representatively good job of boring with a well-known portable boring-bar on a cast-iron cylinder. Graph 2 is a representative job of boring accomplished by another well-known portable boring-bar manufacturer. Graph 3 shows the profilograph record of a good internal-grinding job on a cast-iron automobile-cylinder. Graph 4 is a profilograph record of an attempt to effect mirror finish from a bored hole with an inadequate portable-type tool, using fine-grit stones. This finish looks good to the naked eye when looking into the cylinder, as each of the flat places reflects light and the interstices between the flat places are not visible when viewed longitudinally. Here it is seen that only the peaks of the tool marks, of Graph 1, for instance, have been removed, and it appears highly probable that the interstices between the flat places, as shown in Graph 4, may be filled with abrasive and forced-back metal which possibly works out on to the piston and piston rings, as it is quite obviously difficult to clean out these valleys between the flat places.

Graph 5, in Fig. 55, is the profilograph record of the MicrO-Hone mirror finish which is a new base-metal surface reached by the fast-cutting action of the MicrO-Hone, having removed all of the metal represented in each of Graphs 1 to 4 down to base metal. Since the profilograph measures accurately conditions of surface smoothness in terms of millionths of an inch, and especially since the profilograph will give the same results on each test from any particular specimen, a measurement of the profilograph record is a very accurate method of determining the actual depth of the surface roughness. The magnification of each of these five graphs is 2000 times vertically and 30 times horizontally. All of the graphs were reduced in size exactly in the same proportion for purposes of reproduction in this paper.

Some idea of the close similarity of Micromatic production-hone mirror-finish and MicrO-Hone (field-service tool) mirror finish may be had by comparing Graph 5 of Fig. 55 with Graph 16 at the bottom of Fig. 4.

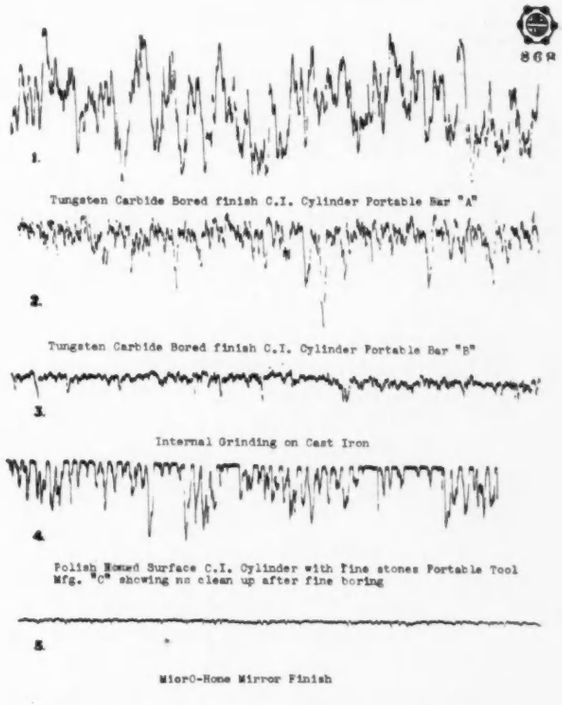

86R
1.
Tungsten Carbide Bored finish C.I. Cylinder Portable Bar "A"
2.
Tungsten Carbide Bored finish C.I. Cylinder Portable Bar "B"
3.
Internal Grinding on Cast Iron
4.
Polish Honed Surface C.I. Cylinder with fine stones Portable Tool Mfg. "C" showing no clean up after fine boring
5.
MicrO-Hone Mirror Finish

Fig. 55—Profilograph Records of Cylinder Surfaces

Surface Finish, and How It Can Be Measured and Specified

By E. J. Abbott

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THIS paper deals with surface finish from the standpoint of the size and shape of the irregularities which constitute the surface. Profiles of a number of common surfaces have been recorded with an instrument called the Profilograph, and these records can be read directly in inch units.

Various machining and finishing operations vary widely, not only in the size of the irregularities, but also in the shape. From this it appears that a single number is not a sufficient specification for a finish when different types of operation are to be compared.

Profilograms of several surfaces are shown, and a brief description given of the advantages and disadvantages of several methods which have been suggested for measuring finish.

LIKE all practical problems, surface finish is complicated by a number of factors such as the material, hardness, and the like, but it seems certain that the most important factors are the size and shape of the irregularities which are the roughness of the surface. Several means have been suggested for rating surfaces, and these will be discussed presently; but, to the author's knowledge, there is only one method of measurement which gives essential data on the sizes and shapes of the irregularities in every-day units, namely, the inch.

Briefly, this method consists of tracing over the surface with a very sharp point, and magnifying and recording the movements of the point so as to obtain an enlarged record of the profile of the surface. An instrument for this purpose has been described in a previous article[1]. It is called the Profilograph[2] because it enables one to record surface profiles. In the present paper, the sizes and shapes of surface irregularities are described briefly on the basis of information obtained with the Profilograph, after which various methods of rating roughness are considered in terms of practical problems of finish.

Size and Shape of Roughness.—Fig. 1 shows profilograms of the surface irregularities of three typical finishes to scale. The outstanding feature of all three surfaces is clearly the extreme bluntness of the irregularities. In each case the width of a hill or valley is from 10 to 50 times its height, and this seems to be a general characteristic of all surfaces measured. The instrument is easily capable of recording much sharper curves and, since there is no trace of sharp breaks, it is concluded that the essential irregularities of surfaces are very dull. This fact should be borne in mind when talking about "bending over peaks," and the like. This dullness is perhaps more easily understood when one thinks of the difficulty of maintaining tools which are sharp in terms of tenths of thousandths of an inch.

A second feature of machined surfaces is the wide range in the size of the irregularities. On rough-boring operations and the like, the profile may have a depth of 0.004 to 0.005 in., while on finely finished parts such as piston pins, gages and the like, the irregularities may be of the order of 5 millionths (0.000005 in.), a factor of nearly 1000 to 1 between coarse roughing operations and fine finishing operations.

A third feature of surfaces is the extreme range in the shape of the profiles. This probably is to be expected from the ease with which various operations can be recognized by inspection of the surfaces. On many surfaces, no two of the irregularities are alike, and the size may vary by a factor of 10 to 1 in a distance of a few thousandths of an inch of profile. For this reason, records of the type shown in Fig. 1 are of slight practical value because they cover too small a length of specimen. This difficulty is overcome by gearing down the recording drum of the Profilograph so that the profile is compressed horizontally by a factor of perhaps 50 or so. This makes all the irregularities appear 50 times as sharp as they are; but, since they are initially so dull, it is still possible to distinguish the individual wiggles. It has been found that about ¼ in. of trace is suitable to obtain a good rating on most surfaces and, on fine finish operations. a still shorter trace is sufficient.

On some surfaces, the profile curves are very irregular, on others, they are very regular. On some, the profiles are essentially flat with occasional scratches, while others are essentially flat with occasional peaks. On most machined surfaces, valleys are larger and more prominent than peaks; but, on some, the peaks and valleys are almost identical in size and shape. Of course, the irregularities are more closely spaced on the finer finishes, and peculiarities of form exist in almost every different type of operation. In fact, most operations can be recognized nearly as easily from the profilograms as from the specimens. Figs. 2 and 3 show profilograms of several typical surfaces.

Specification of Roughness.—It would be desirable if the roughness of a surface could be specified by a single number

[This paper was presented at the Annual Meeting of the Society, Detroit, Jan. 18, 1935.]

[1] See *Automotive Industries*, Aug. 19, 1933, p. 204; New Profilograph Measures Roughness of Finely Finished and Ground Surfaces, by E. J. Abbott and F. A. Firestone.

[2] This instrument was developed in the Physics Laboratory of the University of Michigan on a project undertaken for The Timken Roller Bearing Co. by the Department of Engineering Research. Additional development of the instrument was made in connection with a project for the Ingersoll Milling Machine Co.

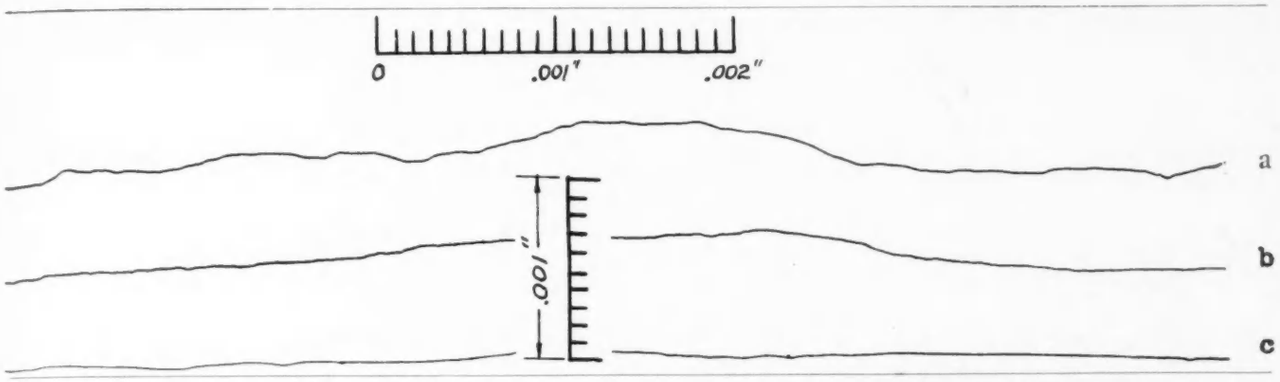

Fig. 1—Profilograms of Surfaces in True Proportion, Showing Bluntness of Irregularities, Magnification 1000X: (*a*) Rough Hone; (*b*) One Feed Mark of Diamond Bore; and (*c*) Finish Hone. (Reproduced Actual Size)

so that a surface could be rated as a No. 6 or No. 10 finish. At first thought, it seems that a number giving the height of the profile would serve this purpose, but an inspection of the profiles of actual surfaces proves that such is not the case. From the standpoint of wear, a surface which is essentially flat with occasional scratches is obviously far superior to one with prominent peaks, or even one which is of sawtooth contour, even though they may all have the same total depth of profile.

After examination of the profilograms of practically all of the usual machining and finishing operations, it was decided that the best approach to specification is the rate at which the bearing area of the surface increases as the upper part of the profile is removed. Measurements were made of the increase of bearing area with depth on a number of profilograms, and the following specification devised on the basis of these measurements. It was found that most of the peaks on a surface are removed when the bearing area is 25 per cent, and that when the bearing area is 75 per cent only the deeper valleys remain. Accordingly, a surface is defined in terms of three heights defined as follows:

Definition of Roughness Numbers

Peak Number.—The height between the 2 per cent and 25 per cent bearing area.

Medial Number.—The height between the 25 per cent and 75 per cent bearing area.

Valley Number.—The height between the 75 per cent and 98 per cent bearing area.

All three numbers are given in inches; preferably, in millionths of an inch for convenience. The 2 per cent and 98 per cent limits were chosen to minimize the effect of a single prominent irregularity. This specification takes no account of the horizontal spacing of the irregularities. If it is desired to do this, it appears that the number of times the profile curve crosses the 50-per cent bearing-area line in a given distance would be a good rating. This method of specification, and the reasons underlying it are described more fully in a previous paper.[3]

Surface Waviness.—In addition to the finely spaced (a few tenths of a thousandth up to a few thousandths of an inch) irregularities which we have termed the "Roughness," many surfaces exhibit another type of irregularity which we have called "Waviness." In general, the roughness and the waviness of a surface are of the same order of vertical dimension (up to 100 millionths of an inch for finishing operations), but the horizontal spacing of the waviness is much greater, of the order of tenths of inches, or more. Fig. 4 shows some typical examples of waviness. The roughness is usually related to "tool marks," while waviness is due to "feed marks," "chatter," and other causes.

Obviously, if one is actually to realize the benefits of a smooth surface, the waviness must be small enough so that the bearing area is determined by the roughness rather than the waviness. It appears that waviness is important on many familiar operations. At present, it seems that the best way to specify waviness is to give the height and spacing of the waves. For example, 10 millionths of an inch high, and 1/16-in. spacing.

Practical Methods of Rating Finish

While the method of measuring and specifying finish just outlined apparently leaves little to be desired concerning data on the size and dimensions of the irregularities, it has one drawback, namely, time (that is, cost). While additional development will certainly reduce the cost of records from the present value of several dollars each on a laboratory basis, it appears to the author that the minute dimensions involved demand a delicacy of instrument, adjustment, and manipulation which precludes its immediate application to routine factory inspection. With this in mind, it is proposed to review briefly the various methods of rating finish which have been suggested, together with a brief statement of the advantages and disadvantages of each.

(1) *Microscopic Examination.*—Ordinary microscopic examination is of slight practical use because one is primarily interested in the height of the irregularities, while the microscope gives a plan view, and hence does not yield definite numerical values. If the magnification is great enough to bring out millionths of an inch, the field of view is so small that usually only a part of an irregularity can be viewed at once. Small depth of focus is another drawback. By using different lighting, one can obtain almost any kind of picture he wishes. Hence this method is of little use in settling arguments.

(2) *Profile Microscopic Examination.*—A method has been devised for illuminating a small area of surface and viewing it at essentially grazing incidence with a microscope so as to obtain a profile view.[4] This is a very simple method for comparatively rough surfaces, such as boring and the like, but is not sensitive enough for finishing operations where smoothness is really a factor.

[3] See *Mechanical Engineering*, September, 1933, p. 569; Specifying Surface Quality, by E. J. Abbott and F. A. Firestone.

[4] Über ein neues Mikroskop zur Oberflächen-prüfung; von G. Schmaltz. Sonderabdrüch auf Zeiss Nachrichten. Heft 7, Juli, 1934.

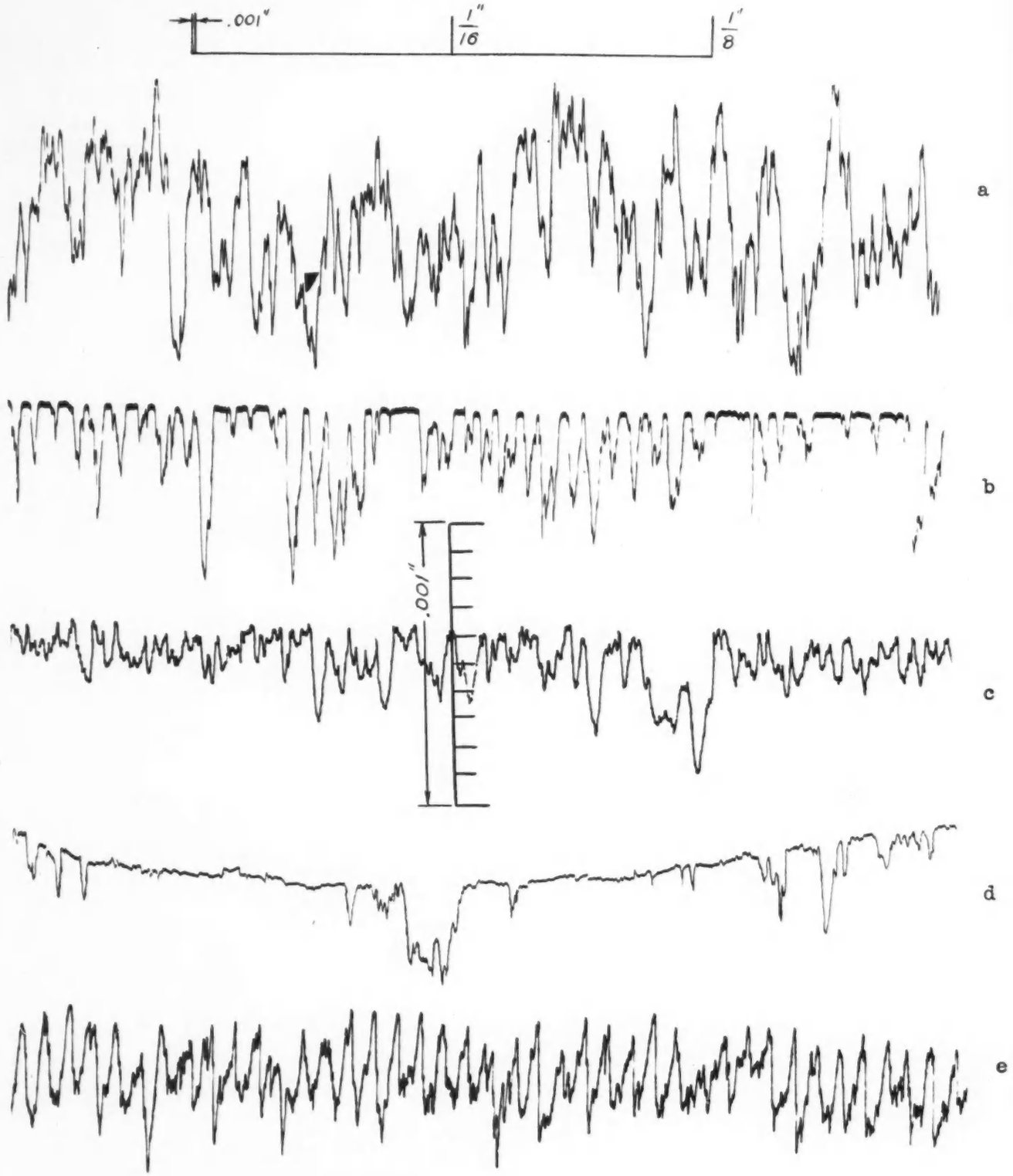

Fig. 2—Profilograms of Several Typical Surfaces Showing Differences in Size and Shape of Irregularities. Magnification: Vertical, 2000X; Horizontal 30X. That Is, the Record Covers about ¼ In. of Specimen. (Reproduced Actual Size)

These records illustrate the sort of profiles obtained, and are not intended to indicate the relative smoothness obtainable with a given operation: (*a*) bore in cast iron; (*b*) followed by partial hone; (*c*) reamed; (*d*) worn automobile cylinder; and (*e*) **"diamond" bore**

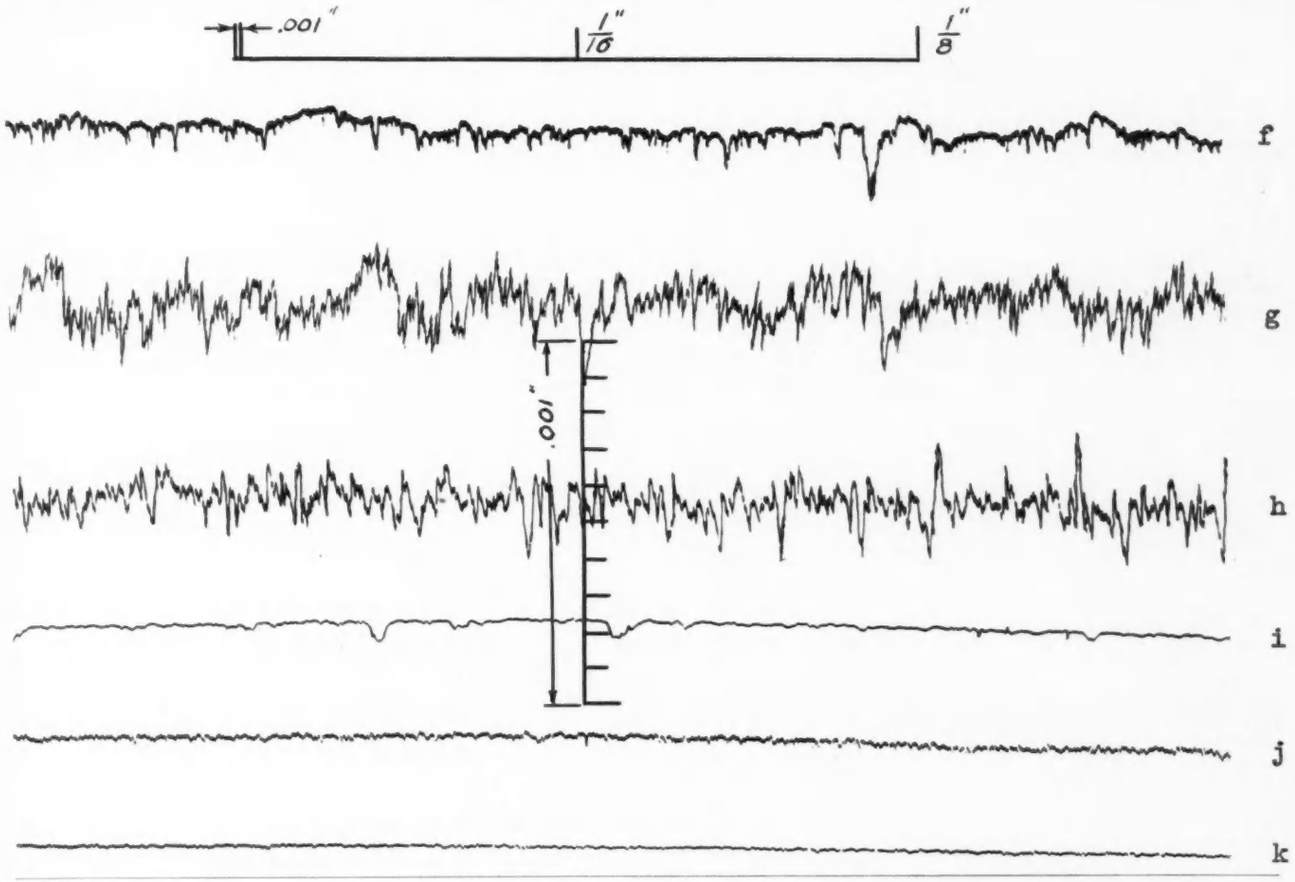

Fig. 3—(Reproduced Actual Size) Profilograms of Several Typical Surfaces Showing Differences in Size and Shape of Irregularities. Magnification: Vertical, 2000X; Horizontal, 30X. That Is, the Record Covers about ¼ In. of the Specimen

These records illustrate the sort of profiles obtained, and are not intended to indicate the relative smoothness obtainable with a given operation: (*f*) burnished; (*g*) ground; (*h*) honed; (*i*) lapped; (*j*) ground; and (*k*) honed.

(3) *Profile Section Method.*—If a specimen is carefully copper plated, cut so as to expose a profile of the surface, and the cut carefully polished, the profile can be examined microscopically, and photomicrographs made if desired.[5] It is believed that this is the best method of studying the details of the shape of any single irregularity (assuming that the shape is properly preserved in the preparation of the specimen). If one uses, say, 1000X to measure the vertical dimensions, he must use several yards of records to obtain a suitable average. This method is so laborious that it seems reasonably sure that it will be used only in special laboratory experiments.

(4) *Pencil-Lead Method.*—An attempt has been made to rate the roughness of surfaces by the rate at which a pencil lead is worn away when it is drawn over the surface at a certain speed under a given pressure. Usually, the lead is mounted on the end of a dial gage so that the wear in thousandths is indicated directly. I never have had an opportunity to compare readings made by this method with profilograms of the surfaces in question; hence, I have no definite information. I have been informed that, while it seems to give a fairly consistent rating, it leaves much to be desired.

(5) *Electrical Pick-Up Method.*—Several investigators have drawn a phonograph pick-up across a surface, and used the generated voltage as a measure of the roughness.[6] The voltage was measured by means of an amplifier and electric meter. This single value obviously cannot give all the information which can be obtained from profilograms, but I am of the opinion that this is the practical instrumental method for routine inspection. However, some of the outfits have been assembled without a proper appreciation of the electrical factors involved, and it is my opinion that such instruments should be regarded as special-purpose devices, developed for a specific inspection after comparisons with profilograms, and proper adjustments in the electrical circuits to insure proper agreement. They should not be used for general rating purposes without check.

(6) *Visual Comparison with Profilographed Standards.*—The old "eye-and-fingernail" method of judging finish often leads one far astray if he is trying to compare different types of operation; as, for example, ground, lapped, and honed surfaces. It just cannot be depended upon for this purpose. On the other hand, if one has several specimens of a given operation, as, for example, grinding, of varying degrees of roughness, they can be unerringly placed in the correct order

[5] See *Transactions of the American Society of Mechanical Engineers*, 1931; Appendix 1 to Paper No. MSP-53-12; Microscopical Examination of Cross Section of Surfaces, by C. B. Sawyer.

[6] See *Transactions of the American Society of Mechanical Engineers*, 1931, Paper No. MSP-53-12; A Survey of Surface Quality Standards and Tolerance Costs Based on 1924-1930 Precision Grinding Practice, by R. E. W. Harrison.

of roughness by ordinary inspection. This immediately suggests a method of checking finish which is both economical and accurate.

When one is making preliminary decisions regarding the relative finish obtained by different operations, or by different machinery, or is setting up limits, or wishes to settle an argument, the answer is profilograms of selected specimens. For routine inspection, visual comparison is made between the production finishes and the standard specimens of the particular operation in question.

Conclusion

Means are now available so that surface finishes can be measured and specified in terms of the dimensions and shapes of the irregularities which are the roughness and waviness of the surface. Sufficient profilograms have been made to indicate something of the complexity of the problem, and to prove the necessity of more than one number for specifying roughness so that account can be taken of the *character* of the surface, as well as the *size* of the irregularities. A set of three numbers has been devised which appears to be sufficient for specifying most finishes in use today.

For routine checking of finish it appears that visual comparison with standard specimens, and special-purpose electrical-meters are most promising. In both cases, they should be based on, and correlated with, profilograms, and the Profilograph be used to settle all arguments. Additional developments will also improve the Profilograph. Of course, the real reasons for fine finish have to do with wearing qualities, lubrication, and the like, and it is hoped that now that means are available for knowing what surfaces are being tested, such studies will be undertaken.

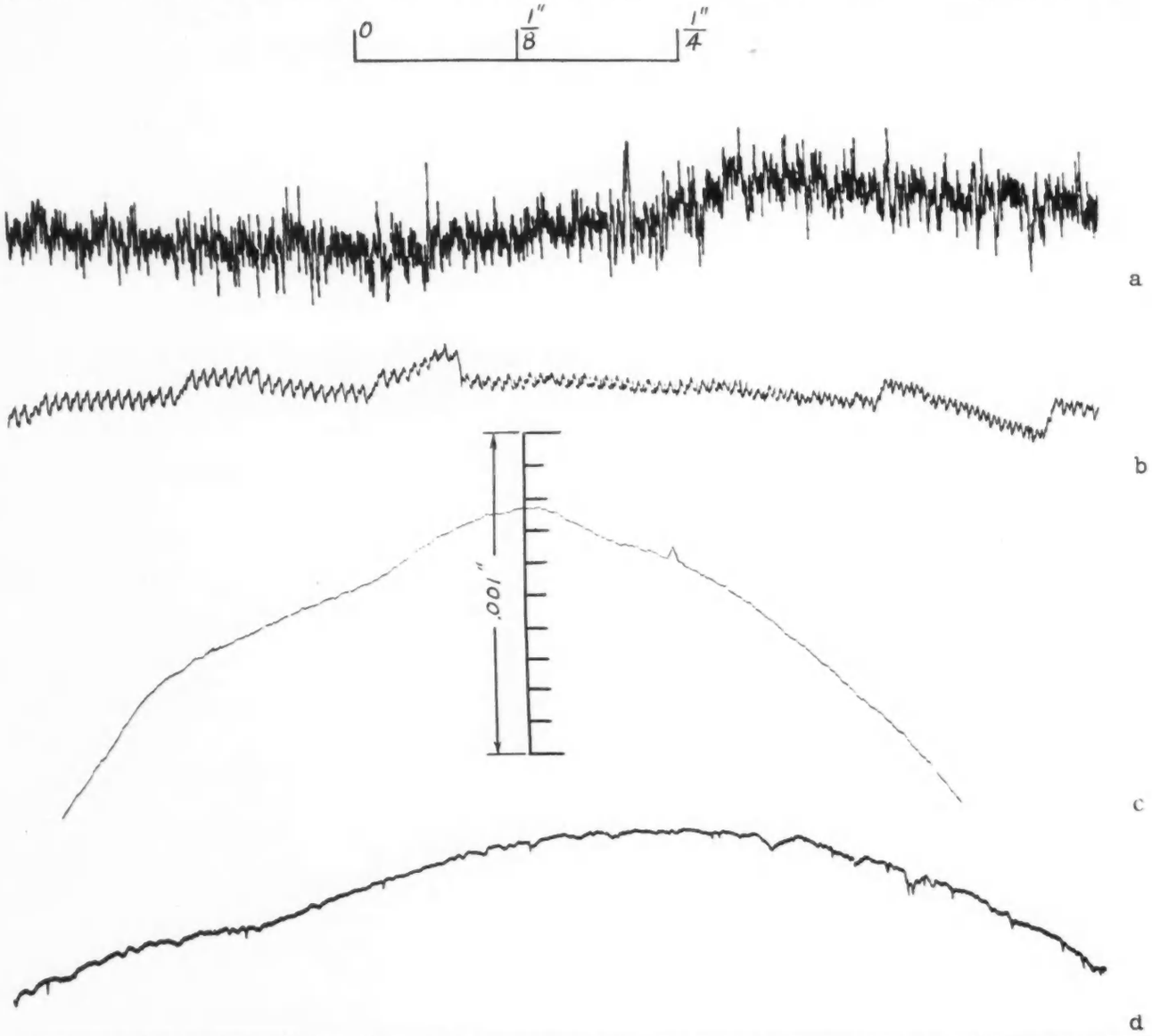

Fig. 4—(Reproduced Actual Size) Profilograms of Typical Surfaces Showing Waviness, as Well as Roughness. Magnification: Vertical, 2000X; Horizontal, 8X. That Is, the Record Covers about 1 In. of the Specimen

The records cover (*a*) surface operation; (*b*) bore; (*c*) small waves of about 0.00005-in. height by 1/10-in. spacing on a smooth, slightly curved surface; and (*d*) a worn automobile cylinder.

Discussion at Annual Meeting

in Digest

HERE are digests of the *discussion* which took place following the reading of papers at the 1935 Annual Meeting. (Digests of the papers themselves appeared on pages 33-39 of the February issue of the S.A.E. JOURNAL.)

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One of the papers read at the Annual Meeting was printed in full in the February issue. Others appear in full on other pages of this issue.

Still other papers and discussions will be printed in full later.

* * * *

Mimeographed copies of all *papers* will be available, until current supplies are exhausted, at a cost of 25 cents per copy to members; and at 50 cents per copy to non-members. Orders for mimeographed copies must be accompanied by remittance and should be addressed to Sessions Secretary, Society of Automotive Engineers, 29 West 39th St., New York.

Transportation and Maintenance Session

Papers at this session: (See page 33, February issue, for digests)—

How To Finish A Truck—*P. R. Croll, Pittsburgh Plate Glass Co., and L. E. DuBey, Ditzler Color Co.*

How to Buy a Truck—*T. L. Preble, Tide Water Oil Co.*

L. V. NEWTON, chairman of the session, considers the repainting schedule for trucks of 15 months, as indicated in Mr. Preble's paper, too brief. He would like to see trucks repainted every two years, believing that to be often enough with present-day finishes, and that the job should be completed in two days for each truck.

On the selection of vehicles, T. C. Smith pointed out that state legislatures have already set up radical requirements for the performance of burden vehicles. The individual operator may be able to select a vehicle that will move his goods economically and comply with the performance regulations of the states in which he operates, while still neglecting the necessity of keeping his vehicles "out of the way of" the high speed vehicles which are the major users of the highway. Unless this consideration is kept firmly in mind, Mr. Smith believes, further drastic restrictions may be expected from the state legislatures in the near future.

Leo Huff injected the statement that in the petroleum-distribution industry, one of the things now influencing the specifications of tank trucks is the credit situation. It is becoming necessary to deliver petroleum products in smaller lots, Mr. Huff believes, which necessitates more sections in tank trucks and more trucks in service, if frequent deliveries are to be maintained.

Mr. Huff also challenged Mr. Preble's position that it is not desirable for a fleet operator to standardize on one make of truck. Such a position is tenable only when a truck, selected for its specifications, cannot be serviced in all the fields where the operating company functioned, Mr. Huff said.

Mr. Preble replied that he believed standardization on one make of truck is a "psychological" error in that the supplier of that truck is led to believe that he had the business "salted away." Such a view stifles progress, according to Mr. Preble, and should be discouraged. He later qualified his view to the extent of recommending standardization on a minimum number of truck makes which will meet the optimum requirements of the operator.

F. C. Horner said he believes the main problem of the operator, after he had obtained a good truck, is to apply it to the job in hand. Much pitiful misapplication of trucks to hauling requirements has been made, according to Mr. Horner, but the situation is much improved because some operators have studied the problem in a scientific way.

After pointing to the experience of the London General Omnibus Co., which began collecting and analyzing its operating records in 1922 as a prelude to better choice of equipment, Mr. Horner gave some thoughts on the question of reciprocity in truck purchases.

If the vehicle product is right and the price is right, he believes, it is perfectly right for the fleet operator to buy equipment from those companies which make a practice of purchasing their needs from his organization.

Mr. Horner commented favorably on a recommendation that truck design engineers should pay more attention to studying the needs of the users.

Setting up of job standards should be preliminary to the buying of trucks, said Mr. Preble, and indicated that he had in process some studies which would determine, for his purposes, required round-trip speeds on a specific job, etc. In buying a truck he does consider service facilities of the manufacturer, and comparative statistics or specifications of various makes, he added.

A. J. Scaife reminded those at the session that the National Conference on Street and Highway Safety had introduced an ability rating for trucks, requiring that a light truck shall be designed to climb a 3 per cent grade at 20 m.p.h., with full load. Rhode Island has made the test gradient 4 per cent, Mr. Scaife added, pointing out that the old torque factor is ruled out with the use of a rating based on speed.

Major E. C. Wood introduced to the session a detailed consideration of some of the things which must be worked out before a truck is purchased. His outline included mention of highway conditions, legal limitations, ways of performing the hauling job, performance of equipment, and costs. Under "essentials" he listed: (a) Vehicle to be the product of a soundly established organization. (b) Must be a well developed vehicle from the engineering point of view. (c) Vehicle must be manufactured from high-class material, under S.A.E. Standards, and be inspected so as to insure uniform quality of engineering. (d) Must be simple in construction and accessible, in order to facilitate the ordinary work of mechanical maintenance. (e) The service organization of the manufacturer must be so arranged as to be of assistance to the operator.

J. G. Moxey asked some questions about painting, to which Mr. DuBey replied that he agreed that a period of 15 months between paint jobs was too short, and that the second painting should come probably in 3 to 4 years. If many spots have been touched up or repaired between general paintings, it is better to strip the paint down to the metal.

Howard K. Gandelot asked Mr. Preble what considerations should guide an operator in the purchase of new equipment with which he has had no experience.

Asking questions of other operators who have used the particular equipment does not settle the matter completely, according to Mr. Preble. Put the truck on the scale and look over the handbook, he said. Put it on a test route and check its performance against your own data. Examine particularly its average speed, and its fuel consumption.

"If you are too small an operator to permit elaborate testing, you are at the mercy of the manufacturer who sells the truck, but I think the average manufacturer is honest," Mr. Preble continued. The relationship between buyer and seller should be one of complete mutual information, and should be put into writing. "It is up to the manufacturer," he said, "to sell transportation that will meet your requirements, and it should be his function to tell you whether he can provide such transportation."

In the petroleum industry, said J. G. Moxey, the output of motor vehicles is gaged in miles/gallons for each type of truck, knowing definitely that if the quantity of work is not up to normal expectancy, the vehicles are not performing efficiently. The rate of doing work, that is, miles per gallon delivered, is also of the utmost importance in studying the efficiency of routine. This varies with various types of service rendered.

In purchasing equipment, Mr. Moxey said, performance ability must be kept up to a set standard for the territories in which the equipment is to operate, bearing definitely in mind that a hilly territory requires a vehicle of considerably more power than that used in a level district. A study must be made definitely on the relationship of speed ability and investment.

Transmissions of recent design, having a ratio from fifth to fourth and from fourth to third of approximately 7/10, have come very much to the front in heavy-duty delivery units, Mr. Moxey said, and are to be recommended strongly as reducing to a minimum the amount of gear shifting.

The importance of the human element in truck operations was emphasized by J. M. Orr, who complimented Mr. Preble for including reference to driver-location in his paper. Mr. Preble's recommendation to replace individual vehicles as they wore out was also commended by Mr. Orr.

Too much dependence on handbook weights was deplored by Merrill Horine, who pointed out that handbook weights are usually "paper weights" for a standard chassis, while all heavier types of trucks are custom made, and their final weight will depend on the amount of special engineering and equipment which has gone into their makeup.

Mr. Horine concurred in the view that truck purchasers should leave the designing of equipment to the designing engineers, so that servicing of the vehicle shall fit better into the standard service facilities of the manufacturer and that the vehicle itself shall be a balanced design. The buyer should suggest the function of special equipment or design and leaves the means of attaining it to the manufacturer, he believes.

In comparing cost records, Mr. Horine pointed out, it is not fair to compare the performance of a truck on an easy route with one on more difficult service.

Transportation and Maintenance Luncheon

Paper at this session: (See page 33, February issue, for digest)—

Motor Vehicle Design from the Operation and Maintenance Standpoint—Part II—*Fred L. Faulkner, Armour & Co.* (Part I was presented at the 1934 Summer Meeting and published in the JOURNAL, September, 1934.)

B. B. BACHMAN questioned whether the results of the work of Mr. Faulkner's committee would ever harmonize the differences existing in the data which they had to study. Whatever is done, he pointed out, does not change the fact that there are a number of truck companies selling their product to customers with varied requirements, and that even codification of some of their points of view will leave differences of opinion on how the results implied in the codification may be achieved.

Mr. Bachman emphasized, however, that the work of the committee was valuable, and would be made use of by truck manufacturers.

That Mr. Faulkner's report has laid the foundation for something more definite in the way of truck rating formulas, was the contention of E. W. Lager. A question raised by Mr. Lager was the relationship between the gross rating of a vehicle and the displacement of the engine. Using the displacement of an engine in a 1½-ton truck, should the truck of 30,000 lb. gross carry an engine of proportionately larger displacement? Such an engine might prove impractical, Mr. Lager thought.

That truck design engineers should spend more time in the field, was the suggestion of Leo Huff, who said that he had been approached seldom by representatives of the engineering department of a truck manufacturer.

Some additional matters for consideration were suggested by Merrill Horine. Fundamentally, he thought, it would be better to continue Mr. Faulkner's study in the direction of what things are desirable in truck design, rather than what is being offered by manufacturers.

You cannot secure maximum durability and minimum price per 1000 lb., he said, nor maximum strength with maximum fatigue resistance. Accessibility is contrary to simplicity; to make a unit accessible you must make it complicated. He concluded with the thought that it would be better if tables of specification included some of the important things mentioned by Mr. Faulkner, rather than comparatively unimportant information.

If a simple rating symbol could be obtained, T. C. Smith said, it might be of considerable help, particularly to small operators. But he agreed with Mr. Bachman that such a symbol was not obtainable.

Favoring Mr. Horine's method of checking ability, Mr. Smith went into some detail on "one way of looking at a truck." Assuming a truck designed for 11,000 lb. gross weight, he said, suppose you want to get a comparison with some of the other offerings in the same field. Take the weight of the vehicle chassis only, without engine and transmission. Knowing that the vehicle is good for 10,500 lb. gross vehicle weight, and dividing that by the weight of the actual stripped chassis, you may get a factor of, say, 3.5. Apply this same factor to other vehicles in the same field and it will reveal unsuspected things. It may be that you will want to use a different factor for a conventional truck than you would for a camelback. Very interesting results can be obtained by this method, according to Mr. Smith.

Closer standardization of the design of accessories and chassis items, not always considered of major importance, would unquestionably be helpful in simplifying operators' problems, said Pierre Schon. But, he said, truck manufacturers are compelled to build and equip vehicles to meet a great variety of operating conditions.

A truck used in daylight service requires a minimum of lighting equipment, while one used in night service, particularly if it drags a trailer, will require much larger generator and battery equipment, he pointed out.

Dimensional figures are not the only index of clutch performance. Many other contributing factors must be considered. Other examples were offered by Mr. Schon, before his general conclusion that "there is no question but that Mr. Faulkner's paper has been given careful consideration by the designing engineers of the truck and accessory manufacturers."

The thanks of the Transportation and Maintenance Activity was expressed to Mr. Faulkner and his committee by L. V. Newton, who said that he was particularly pleased with the way manufacturers' representatives had received the paper and its conclusions. The committee had no intention of telling the manufacturers how to design their vehicles, he pointed out, but was simply offering some thoughts on the question which would result in the production of better vehicles for all concerned.

Truck, Bus and Railcar Session

Paper at this session: (See page 34, February issue, for digest)—

Engineering Uses of Rubber—*Curt Saurer, Firestone Tire & Rubber Co.*

F. L. HAUSHALTER, concurred with Mr. Saurer's view that there is a possibility of rubber springs replacing steel springs on automotive vehicles and rail cars. In this connection the rubber engineer has to solve the problems of fatigue of the rubber and its permanent set or sag.

In designing springs, he said, the rubber engineer should be permitted to use the best possible compounds that he has developed, and such compounds will come within a hardness range of about 37 to 85, and preferably 40 to 70, on the Shore durometer.

In application of rubber to springs and shock absorbers, the rubber should not be expected to dissipate a great deal of energy. When rubber is used to dampen vibration by the dissipation of energy in hysteresis or cyclic losses the dissipation is very small per unit of volume. In a successful rubber spring, the rubber should have a minimum of internal loss in fatigue action. Rubber should not be worked to produce a temperature in its mass of more than 15 or 20 deg. fahr. above the surrounding temperature. Higher temperatures mean a sacrifice in the life of the rubber.

In concluding that rubber springs may be designed to give the characteristics wanted by automotive and rail-car engineers, Mr. Haushalter presented a mathematical discussion showing the adaptability of rubber compounds to various spring applications.

Some data on fan belts were introduced by E. G. Kimmich, who remarked that exponents developed originally from studies of flat belts checked so closely with those resulting from subsequent studies of V-belts that the same formula was being used for both types.

All other factors being constant, he said, the length of service in flexing varies directly as the fifth power of the diameters of the pulleys used; length of service varies in inverse proportion to the fourth power of the unit tension, and the sixth power of the thickness and the square root of the belt speed—in each case all factors being held constant except the one being investigated at the time. The actual exponents determined from tests were given in the formula accompanying Mr. Kimmich's written discussion.

A word of caution on increasing diameters in fan drives brought out that in the usual design it would be difficult to change the pulley diameters without changing the tension, belt velocity and belt length at the same time. With some designs now in production, Mr. Kimmich said, the belts operate in excess of 6000 ft. per min. and in some cases above 7000 ft. per min. Under such circumstances, a further increase of pulley diameter would increase the centrifugal tension enough to offset the more favorable diameter. The formula given predicts such a result. If the belt speed is below 6000 ft. per min. an increase of pulley diameter very likely would give an advantage in belt life.

Walter C. Keys pointed out that the meager information available about the uses of rubber is sometimes misunderstood and misapplied, and that a little pertinent assistance will enable a seemingly difficult problem to be cleared up satisfactorily. He subscribed to Mr. Haushalter's view that the minimum hardness of rubber safe for engineering use was 30 durometer.

In reply to a question from B. B. Bachman, Mr. Haushalter said that 160 deg. fahr. was about the highest temperature under which rubber could work, if it is to have any life at the end of 2 or 3 years.

M. C. Horine asked about the relative strength of experimental rubber springs as compared with steel springs, saying that it has been found that the use of rubber becomes less attractive as the weight of the vehicle increases. Mr. Saurer replied by saying that the spring used in the experiments he had discussed weighed about 6½ lb., including the attachment parts, but that his company had developed a new spring which weighs only 3 lb., but which will support a load of 1800 lb.

Use of a molded phenolic-resin cover on rubber steering wheels was mentioned by Herbert Chase, with S. M. Cadwell contributing the information that it was used as a covering because of the color limitations of the rubber.

Aircraft-Engine Session

Papers at this session: (See page 34, February issue, for digest)—

Aircraft and Aircraft Engine Performance as Influenced by Engine Oils—*S. D. Heron, Ethyl Gasoline Corp.*

Winter Operation of Aero Engines—*Alan Ferrier, Royal Canadian Air Force.*

Progress Report of C. F. R. Aviation Gasoline Detonation Subcommittee—*Arthur Nutt, vice-president in charge of engineering, Wright Aeronautical Corp.*

COMMENTING on the papers by S. D. Heron and by Alan Ferrier, caution against using low-viscosity oil in an engine of high output was advised by A. L. Beall. His company's experience is that such light oils are suitable only for starting an engine of reasonably high output. He agreed with Mr. Heron on the desirability of making laboratory tests for stability but said that, in two 5-hr. periods of full-scale engine-testing, the rate at which sludge will form can be determined fairly well and, following the test, considerable information regarding ring-sticking tendency can be obtained.

Referring to Mr. Beall's statement that the temperature of the cylinder walls approaches, in winter, the temperature of summer operation and that the same amount of heat is generated in the cylinder in winter as in summer, Dr. H. C. Dickinson—after assuming that there is a 10 per cent difference in temperature between summer and winter operation and that the same amount of heat is generated in the cylinder in winter as in summer—stated his belief that the inside cylinder-wall temperature may be 40 deg. Fahr. lower in winter than in summer. If so, the difference in cylinder-wall temperature almost compensates between the 63-sec. and the 120-sec. oils, because heating it 20 to 40 deg. warmer brings it to just about the same temperature. Mr. Beall replied that the assumption might be fairly sound if the oil were pumped straight from the oil pump to the cylinder wall, but remarked that the oil passes through some very warm places before it reaches the cylinder wall and said that there would be some change due to this heat.

J. P. Stewart said that, with certain oils, ring gumming is sometimes extremely influenced by temperature and at other times it is not. Rings may stick in 50 hr. and may not stick in 200 hr.

Opie Chenoweth stated that a number of tests have been made by the Material Division of the Army Air Corps at relatively high oil temperatures and that they have worked out very well. He thinks that the entire problem will bear much additional investigation. The Division is now preparing some engines for tests with very high oil temperatures, and these will throw considerable light on the problem of wear. He feels that the points brought out by Mr. Ferrier regarding the control of viscosity are sound. In the Air Corps, three grades of oil are used. It was found that, when the oil was changed, the problem of maintaining the proper viscosity was rather serious. In consequence, one of the accessory manufacturers supplied test data on automatic viscosity-control, so that, regardless of the oil used in the engine, the viscosity tends to remain constant. Mr. Chenoweth feels that this is a real step forward in the use of widely different grades of oil, particularly for aircraft engines which must cover a large range of territory and the temperature differences may be great.

Arthur Nutt recalled work done by his company about five years ago in which an engine was flight-tested with heavy and with light oils. He said that a light oil could not be used without danger of wearing the cylinders badly. Therefore, a system for adding the light oils with caution was developed. Two tanks were installed; one containing the extremely light oil to start the engine, the other, the heavier oil to use after the engine was thoroughly oiled. The only bad feature was that, in a plane making numerous stops, the oils would mix very quickly. Keeping the engine in a warm hangar is another system which warrants consideration for the type of work done in Canada.

E. F. Hallock feels that any excess wear encountered while using light oil should not be attributed wholly to viscosity. He suggested that it may be due to the oil breaking down at the piston rings because of being too hot, or because of cylinder distortion or of ring blowby. He remarked that wear is no greater when using extremely light oils in automobiles.

J. H. Geisse noted that, in measuring the oil-outlet temperature of the normal engine, one really does not measure the hot oil. It is a mixture of a hot oil coming from the engine with a certain amount of oil the temperature of which has not changed at all. The percentage of that admixture determines what the outlet-oil temperature will be relative to the actual operating temperature.

Mr. Heron remarked that the Air Corps has had little or no experience regarding the amount of wear caused by using 55-sec. oil at cruising speed. At full throttle, it was found that wear was excessive. However, it was felt that an engine which would start and would wear was better than one that would not wear but would not start. Referring to the critical temperature of ring gumming, he said that some of the work at Wright Field has indicated that some oils are extremely satisfactory at one temperature and just as satisfactory at another temperature; and then, when the temperature is raised about 20 deg., there is a great change in the reaction.

Concerning Mr. Ferrier's point about the danger of using very volatile aviation gasolines on account of vapor locking, Mr. Heron cited a case in which gasoline of a vapor pressure of 17 lb. per sq. in. and an end-point of 110 deg. Fahr. was used with extremely satisfactory results up to 25,000-ft. altitude when the ground temperature was 32 deg. Fahr. Dr. Dickinson then remarked that it is quite certain that there is much more to be done in the way of adjusting a starting fuel, gasoline, in such a way as to get good starting up to —45 deg. Fahr. He said that, without question, gasoline can be made to start an engine at —45 deg. if other conditions are kept under control; that is, without overheating and with correct distribution. It is a question of suiting the gasoline to the purpose, he said, and he thinks that the possibilities along the vapor-lock line have not been exhausted.

F. W. Caldwell's opinion was that the sticking of valves in airplane engines is comparatively infrequent in comparison with similar trouble in automobile engines. In aircraft practice, the guides on the exhaust valves are nearly all cut off flush, while in the automotive field it is still the practice to run the guides into the passage. They are of cast iron; they bulge and they grow when heated and make a fine place for gum to collect. Corrosion also takes place when much sulphur is in the oil and, eventually, the valves stick. To this A. L. Beall replied that if the rocker-box lubricant is heavy grease, possibly containing water, it may get stiff or even freeze so that the valves are held off their seats, in which case it is impossible to start an engine.

In conclusion, Mr. Ferrier said that he had been warned of the penalty of excessive wear through the use of low-viscosity oils in winter. So far, he said, we have had no experience with engines of high specific output. Naturally, we approach such engines with very great caution. However, on engines of lower specific outputs, this question of wear has not been borne out by our actual experience, either as to cylinder wear or oil consumption.

Aircraft-Engine Session

Paper at this session: (See page 35, February issue, for digest)—

Fuel Injection as Applied to Aircraft Engines by the United States Army Air Corps—*J. F. Campbell, Power Plant Branch, Materiel Division, U. S. Air Corps.*
(Paper published in full, pages 77 to 88, this issue)

THE fundamental character of the fuel injection principle was emphasized by Mr. Nottingham, who characterized it as a step toward Diesel or semi-Diesel features without many of the attending difficulties connected therewith.

F. C. Mock termed Mr. Campbell's paper a brilliant piece of research work, and asked for further details concerning the compression ratios and boosting pressures mentioned therein. To this Mr. Campbell replied that, in general, all tests on the 1340-type power-sections were standard, except for one special test. He then discussed the various compression ratios and commented upon the supercharging used. Regarding the volume contained in the induction system from the point of discharge to the combustion chamber—mentioned in the paper—he said that this should not be more than 35 per cent of the piston-displacement values. Except for some special fuels, mentioned in the paper, all the fuels had a No. 87 octane rating.

J. H. Geisse emphasized that one of the serious hazards in commercial operation lies in the formation of ice in the carburetor and manifold. He said that several recent accidents have been traced to that cause.

M. G. Chandler mentioned that the first patent on his device was taken out in 1914. The first installation was on a Chrysler four-cylinder engine, which was operated on a test stand and was never tried in a car.

Passenger-Car Suspension Session

Papers at this session: (See page 35, February issue, for digest)—

The Properties of Tires as Affecting the Riding, Steering, and Handling of Automotive Vehicles—*R. D. Evans, The Goodyear Tire & Rubber Co.*
(Paper published in full, pages 41 to 49, Transactions Section, February issue)

Farewell to the Horseless Carriage—*Elliott G. Reid, Guggenheim Aeronautical Laboratory, Stanford University.*

Transverse Leaf, Independent Springing—*Karl K. Probst, Consulting Engineer, Leaf Spring Institute.*

DISCUSSING R. D. Evans' paper, R. W. Brown recalled that the Society has been sponsoring riding-comfort research for a number of years and remarked that a number of factors are connected with riding comfort. Just exactly where the optimum ride will be, depends upon the measuring means of valves involved. "We cannot get the ideal ride at the expense of steering or at the expense of riding comfort," he said. "In my opinion we can only get the compromise by measuring the complexities and it involves a large amount of measurement, particularly that which has to do with the preference of the rider in the automobile; whether he prefers emphasis on steering power or on the ride that some of the test riding gives with the new spring-suspension."

Many car engineers, K. D. Smith said, in their desire to overcome one difficulty have asked the tire engineer to put something into the tire that may affect the quality in some other way. He hopes that the car engineers will take this to heart, particularly as to the effect of contact area. Contact area and cornering power, he said, are two factors that oppose each other.

Replying to a query from Mr. Smith, Mr. Evans said that the cord angle has considerable effect upon the wear of the tires. He suggested the possibility of having tires on the front different from those at the rear; perhaps ideal tires for cornering at the front and tires which will give the utmost of wear at the rear.

O. E. Kurt, in prepared discussion, based on his interpretation of the results presented in the paper by Mr. Evans, stated that the characteristic termed "cornering power" is perhaps more familiar as "lateral stability." The first part of the curve in Fig. 1 in the paper is a straight line because of the elasticity of the tire, and represents the distortion, he said. The upper part of the curve slopes off when the lateral force exceeds friction and lateral displacement at the surface occurs. The curves in Fig. 2 are drawn as straight lines, Mr. Kurt continued, but the author did not state whether they were actually of such shape or whether data were not sufficiently accurate to indicate reliably any other relationship between cornering power and camber. The same situation arises in Fig. 11, where the relationship between static torque and radial load is not a straight-line relationship as shown, experience and reason dictating that the curves should pass through the 0-0 point, and then through the region for which Mr. Evans obtained data with a gradually increasing slope.

Figs. 3 to 8 of the paper are in agreement with Mr. Kurt's knowledge of theoretical and experimental work on this subject, which is, he said, inadequate to criticize Figs. 9, 10, 12. Mr. Evans' selection of the word "precession" is, in Mr. Kurt's opinion, rather unfortunate because, as Mr. Evans explains, it has nothing to do with gyroscopic action. "Steering effort" is a more familiar name for the phenomenon which he calls "static torque," according to Mr. Kurt. His further opinions are that an explanation of the relationships involved in each of the illustrations in the paper would be desirable. An understanding of these relationships might lead to improvements in lateral stability without sacrificing comfort or "cushioning ability." A more complete discussion of the implications involved in these relationships should also be included. At present there seems to be a conflict between the author's contention that "it is impossible for a hard-rimmed wheel to develop a large cornering power," and the results in Fig. 8 which show that the cornering power increases as the pneumatic tire approaches a hard-rimmed wheel; that is, as the inflation pressure is increased. The probable existence of an optimum inflation pressure, a maximum in the curves of Fig. 8, would explain this anomaly. The ratio between front and rear mileage is interesting; the value "196" obtained on the more recent tests is more in line with Mr. Kurt's experience than the value "135" reported at first, for conventionally sprung cars. The more recent figures are based on only 2400 miles, which would seem too low to give reliable figures, but there is a sufficient number of cars in the test so that the data are well worth presentation. Although Mr. Evans says that the data are not sufficient to afford "sweeping conclusions," it is Mr. Kurt's opinion that they are adequate to give a fairly reliable indication of the existing situation.

Chairman W. R. Griswold commented on Mr. Evans' work, saying in part that, about two years ago, when many were in the midst of experimenting, designing, or testing some form of independent-suspension system, problems were encountered which were not understood. When one change was made to effect an improvement, that same change would effect a disadvantage in some other way. In connection with independent suspension, Mr. Griswold said, such problems were faced as the stability of tires, the cushioning of tires, steering effort, the

ability of tires to make turns, and that factor of the tires which influenced the handling of a car at high speeds or in high winds. Engineers particularly concerned with the problem contacted with the tire companies, and much information was obtained.

Solution of the suspension problem will be furthered greatly, Mr. Griswold believes, by the work the tire companies have done and by the data recorded in Mr. Evans' paper.

Lee Oldfield, from his experience with the steering and the slippage of racing cars, said that it has been conclusively proved that erroneous opinions have been held regarding weight distribution and its effect on control. There has been a general opinion, he remarked, particularly in the engineering fraternity, that cars with a heavier front end are more steerable. He mentioned the difficulties an experienced driver would have in transferring from one car to drive another car having a different system of weight distribution, and said further that those who are building cars with heavier front ends may have something to be responsible for.

E. S. Hall commented that the rear-engined car is unstable because the greater weight is at the rear, but partly agreed with Mr. Oldfield that weight distribution in which too much weight is carried in front creates a very dangerous situation.

Commenting on Prof. Reid's paper, Chairman Griswold remarked that air resistance at low speed does not amount to much but that, whether or not this is true, its importance lies in how far aerodynamic refinement has been carried and whether it has resulted in something the public will buy and pay good money for.

In the written opinion of Prof. T. Edward Moodie, of the Daniel Guggenheim School of Aeronautics, Georgia School of Technology, Atlanta, frontal area is a poor parameter to use for comparison of drag. The use of frontal area as a fundamental parameter in aeronautical work was discontinued several years ago except for a few special applications. It would seem to be much better to use equivalent flat-plate parasite-area or simply drag area, that is, an hypothetical area the drag coefficient of which is 1.0. Unless these or similar parameters are used, it will be impossible to compare correctly and easily the relative degree of streamlining of cars of different sizes and shapes. After all, Prof. Moodie states, the problem is to transport two or more passengers with a minimum resistance. Reducing the drag coefficient while at the same time increasing the frontal area may not result in any material advantages. Prof. Reid's statement that the rear-engined type is clearly indicated is in Prof. Moodie's opinion entirely too definite a conclusion to draw from the facts at hand. No doubt the front engine-location presents certain obstacles to proper streamlining. But to say that streamlining cannot be effectively accomplished without moving the engine to the rear is entirely unwarranted. It might be said that in a conventional four-wheeled car which is steered by deflecting the front wheels and in which the engine is high, narrow, and long rather than short, low and broad, that proper streamlining with the engine in front cannot be successfully accomplished. But there is no fundamental reason other than custom that causes cars to be built in this manner. It is hard to see why it should be assumed that a rear engine-location is a solution of all our difficulties, Prof. Moodie continued. Such an assumption ignores cooling problems, the increased danger in a crash and, worst of all, the instability about the yawing axis resulting from the rearwardly located center of gravity.

Prof. Moodie has tested a front-engined streamlined-car in the wind tunnel and on the road and stated further that this car was only 14 ft. 7 in. long and had a drag coefficient, as determined in the tunnel, of 0.169. A refined model only 15 ft. 5 in. long had a drag coefficient (C_D) of 0.135 as determined in the tunnel, which is considerably less than the value of 0.164 referred to in the paper. The full-scale machine actually has been driven over 1100 miles and, from this test alone, it would seem to indicate that a high degree of streamlining can be effected without moving the engine to the rear.

"It seems unfortunate that, in such an able piece of research as this paper presents," Prof. Moodie says, "the question of stability of the car about the yawing axis should be ignored, especially in view of the fact that the conventional style of motor car is not fundamentally stable about its yawing axis and streamlining such a car and then moving the engine to the rear will most certainly make a bad condition worse. This fact is well illustrated by the behavior of the so-called Dymaxian rear-engined car which turned over during a run, probably as a result of instability about its yawing axis.

"The only other rear-engined car with which I am familiar is Sir Dennistoun Burney's car which is considerably longer than the average standard car. I do not wish to discount the remarkable advantages to be obtained from proper streamlining, but Prof. Reid does contend that an investigation of drag effects only is not sufficient. In the study of high-speed motor-cars it is essential in addition to investigate stability about both the yawing and pitching axes as well as controllability about these axes and the effects of side winds before recommending radical changes which will offer only an improvement in drag characteristics."

Prof. W. E. Lay pointed out that airplane engineers are accustomed to think of a vehicle that goes straight through the air; whereas with the automobile, since the wind often meets it at an angle, a car should be streamlined at the side as well as at the front. In fact, it should be streamlined in every respect. Another point was that streamlined cars do not raise so much dust.

Taking the subject broadly and in the light of present economic conditions, Chairman Griswold said, the ultimate development of a motor car brings out all of the advantages which can be obtained by really streamlining it, which will depend upon a number of factors. One is style. The public wants the things it is accustomed to. Changing people's habits requires a long time. People who like a long hood will resist being set out in front, although young people may take to the fad overnight. At present, there is an overproduction of motor-car fuels; so, from the standpoint of conservation, we are not particularly concerned with low gasoline-mileages for high-speed driving or ordinary driving. We are solving that problem a little at a time and improving economy each year without going to extremes in our design; but these scientific developments, especially those mentioned by Prof. Reid, may in the future be highly important. Chairman Griswold emphasized that any development which is fundamentally sound will ultimately become materialized.

E. S. Hall disagreed with these latter remarks by Chairman Griswold. If streamlining is going to come eventually, he said, "Why not now?" Fuel economy, he continued, may not be important to those who drive high-priced cars, but it is important to many who do not. Style, in Mr. Hall's opinion, has been overstressed. The public will accept a new style, he said, if it is right. One reason some new styles have not been accepted has been because they were not done well enough.

Lee Oldfield backed up Mr. Hall's statements adding that: "We will never accomplish anything so long as the attitude of the designing engineer is negative. We all appreciate the presence of economic problems involved in commercial automobile design, but that is no reason why discussion of existing problems should be avoided."

Chairman Griswold denied that car engineers are ignoring the vital problems which face them. "Some people merely are bolder than others in doing new things," he said, "and some people can better afford to do such things than others."

Diesel Engine Session

Papers at this session: (See pages 35 and 36, February issue, for digests)—

Cylinder Events Studied in the Logarithmic Diagram—*Alfred T. Gregory, Wright Aeronautical Corp.*

A Rational Basis for Comparing Diesel Performances—*E. S. Dennison, Westinghouse Electric & Mfg. Co.*

DISCUSSING Mr. Gregory's paper, Prof. L. C. Lichty stated, among other things, that this paper presents a method for analyzing indicator cards which, in principle, is excellent but which, in application, is in considerable error. There are two points upon which the analysis depends, Prof. Lichty said, which introduce the errors in question; namely, (*a*) the determination of temperature on the expansion curve from the indicator card, and (*b*) the extrapolation of the expansion curve and the use of temperatures and energies at the extrapolated points. By detailed analysis, he then showed how errors may be introduced.

Prof. Eugene Fezandie submitted written discussion in which he wrote: "While the use of the logarithmic diagram as applied to the indicator card is not new, Mr. Gregory has made a very valuable contribution in his analysis of events in the cycle. The method is simple and direct. The probable accuracy of results appears to be well within the limits of usefulness. So far as I know, his method employing the use of isothermals for obtaining maximum temperature has not previously appeared. I believe that his use of Ricardo's energy-temperature diagrams should permit fairly accurate investigation of indicator cards. Apparently, the method is applicable to a rather wide range of card types."

E. T. Vincent said that, with a gasoline engine running under fairly high output, flame actually comes out of the exhaust pipe; which shows that the combustion is not complete. But with the Diesel engine under high output, practically no flame is in the exhaust, which shows that the combustion efficiency is higher. He then commented upon the curve-charts given in the paper, and suggested that Mr. Gregory add a curve from a modern Diesel to extend the paper somewhat.

E. S. Dennison discussed Prof. Lichty's remarks in relation to proper means of arriving at maximum temperature, saying that if the volume content or standard volume of the gases in the cylinder were known, then the temperature would be correctly determined as Prof. Lichty

pointed out. He believes his method is more nearly correct than the one described by Mr. Gregory, but said that either one is approximate.

Mr. Gregory discussed dissociation curves. He stated that the whole idea was to find a quick method of indicator-card analysis. The exponent for adiabatic expansion which he found in two of the diagrams is the average exponent for the length of diagram shown and does not represent the individual value at any point. The actual adiabatic would be a curved line, as Prof. Lichty pointed out, but Mr. Gregory said that he is not sure just how curved that line would be. In preparing his paper, Mr. Gregory said that he was not able to make any indicator diagrams of solid-injection high-speed Diesel-engines.

Referring to Mr. Gregory's discussion of the logarithmic diagram, Dr. H. C. Dickinson wrote, in part, that he had long been surprised that this extremely powerful tool has been so neglected. Its possibilities in the solution of practical problems are only suggested by the interesting examples which Mr. Gregory cites. There may be two reasons for the long neglect of this tool. The physical significance of a straight-line plot on logarithmic paper is very difficult for most of us to grasp, he said, confessing his own inability to picture clearly what it means in mechanical terms. However, it is not over-difficult to learn its meaning and the possibilities of its use in much the same way that one uses a slide rule or a log table without keeping in mind any of the steps whereby the tool has been developed.

Perhaps a more important reason for the neglect of the logarithmic diagram is that in most cases it does not give accurate figures, Dr. Dickinson continued. In fact, it must be used with discretion to get even useful results. However, when so used, it does give results amply accurate to answer many practical questions which can be answered only with great difficulty, if at all, by any other method. In fact, in many cases, the methods of tedious calculation which otherwise would be required are not any more accurate, often less so. They all involve about the same assumptions and approximations.

I. J. Snader, referring to the discussion of the effect of air density in E. S. Dennison's paper, commended the author's consideration of the effect of air density as a whole rather than as the effect of pressure and temperature considered separately. He thinks that the author has shown adequately that this can be done and that this is a valuable contribution to the knowledge of comparing engine performance under different atmospheric conditions.

Privately-Owned Airplane Session

Papers at this session: (See pages 36 and 37, February issue, for digests)—

Are We Giving the Average Private Operator the Airplane Most Suitable to His Needs?—*Frank S. Spring, Hudson Motor Car Co.*

Sales and Technical Problems of Private-Commercial Airplanes—*Peter Altman, Consulting Engineer, Stinson Aircraft Corp.; Director, Aeronautics Department, University of Detroit.*

Air Transportation Equipment for the Private Owner —*John H. Geisse, Chief, Aeronautics Development Section, Bureau of Air Commerce.*

T. P. WRIGHT, chairman, remarked that the private-owner field in aviation has been sadly neglected during the past five or six years and concluded that anything which will popularize flying is worthy of consideration.

F. S. Spring advanced the opinion that a primary consideration in the path toward a cheaper airplane is a cheaper engine, pointing out that some automobile engines might be adapted to the purpose, if it were kept in mind by their designers that lighter metals could be substituted in the manufacture of some parts, using the same tools. This might get away from the fact that a cheap airplane engine can hardly be produced in small quantities, Mr. Spring thought.

Referring to a statement in Mr. Spring's paper that in the case of blind flying, instruments might be simplified to make the airplane more stable, Mr. Coplin of the Massachusetts Institute of Technology brought up the question of the desirability of such stability.

Mr. Spring replied that an airship should be spirally stable, adding that in blind flying the pilot would confine himself more or less to the use of either the compass, or the turn indicator. Neither instrument is quite scientific enough, according to Mr. Spring. The safest ship under blind flying conditions is the one which best can stay on the course.

Louis Schwitzer, speaking as a private owner, objected to the magnitude of some of the operating cost figures given in the paper by Mr. Spring. Fifty gallons of gasoline are enough for the ordinary trip by a private operator, he said, adding that the gasoline cost per mile in his airplane is less than that for his automobile. Storage and depreciation costs are less than those set by Mr. Spring, in his opinion.

Prof. W. F. Gerhardt suggested setting up ideal specifications for the airplane designed for millions of owners, instead of thousands, and keeping such ideal specifications in mind through any subsequent discussion. He emphasized the importance of giving consideration to rotating-wing aircraft, and other types which might be capable of nearly-vertical landing angles.

In replying to Professor Gerhardt, Mr. Spring offered the possibility of an airplane which would also serve for ground travel under certain conditions. Such a vehicle, he believes, would offer the maximum in utility to the private owner, and such maximum utility should be the first consideration after the problem of designing a plane which the public can afford to buy in quantities.

Prefacing his paper, Mr. Geisse remarked that the cost of instruments is partly due to the peculiar flying characteristics of the present-day airplane. When an airplane more fundamentally stable is built, he believes, many of the night-flying instruments can be dispensed with. (Subsequent discussion included the papers by Messrs. Geisse and Altman, because of time limitations.)

The apparent conflict between angle of attack and angle of flight-path was amplified by Ralph Upson, who said that the two concepts had nothing to do with each other. The spot where an airplane is going to land is under some conditions almost independent of what angle the flight-path takes originally.

The angle of flight-path relative to the ground depends upon a number of things, including the angle of attack, throttle opening, flap settings if used, the elevator setting and the wind.

Mr. Merrill of the Stinson Co., objected to a previous statement that the present airplane is more or less unsafe, pointing out that members of the Stinson Operators' Association from May, 1933, to June, 1934, flew more than 3,500,000 miles without an accident. He reviewed the Department of Commerce requirements regarding the spinning characteristics of a plane which must be established before it can receive a license, adding that there are some safety factors that he would like to see added to the requirements.

Referring to a statement by John Geisse that a propeller much less noisy than is common now could be expected in the near future, E. G. Reid asked what principle would be used in its development and where the development was going on. Mr. Geisse said later that the development looked promising but that was all that could be said about it for the moment.

One discusser expressed the opinion that noise reduction in airplanes is really important. His indictment included both internal and external noises of the plane, but his remarks indicated that he was pleased with reduction of internal noise now attained and directed his criticism principally to external noises. R. F. Norris agreed with the substance of these remarks.

Professor Altman supplemented his paper with some figures indicating the status of private owners in the airplane field. Of these owners, he said, 39 per cent are business executives, 28½ per cent are occupied in skilled tasks, 13 per cent are professional men and the rest fall mostly in the personnel and sales field.

He pointed out also that 60 per cent of the owners of private planes are married.

Diesel Engine Session

Papers at this session: (See page 36, February issue, for digests)—

Progress Report of Volunteer Committee on Compression Ignition Fuel Research—*T. B. Rendel, Shell Petroleum Corp., chairman.*

Design and Development of Fuel Injection Apparatus for High Speed Diesels—*C. R. Alden, Research Engineer, Ex-Cell-O Aircraft & Tool Corp.*

HARTE COOKE stated that the Compression-Ignition Research Committee's tentative program and schedule of fuels made in the spring, 1934, was planned as a means of try-out, to see how well it would work. The idea was to make a tentative schedule that would help the users of Diesel engines; so that, if an engine would work, say,

on a No. 2 but not on a No. 3 fuel, the data would provide means for changing the No. 3 fuel somewhat so that it could be used.

C. L. Cummins, commenting generally on Mr. Rendel's report, said that, in the preparation of cars for the 1934 Indianapolis Race, 20 to 25 different samples of fuel were available and that there was little or no difference in their performance. If certain reasonable limitations were followed, the results were satisfactory.

Chairman Young commended the work of the Committee in working out standards for gasoline fuel saying that, without such data, the high compressions used in engines today and their present performance ability would not be possible. Further commendation was given by Max Hofmann, who said also that as soon as right standards in rating the thermal stability of fuels and the characteristics of fuel oils have been determined a decisive step forward will have been made.

Dr. A. E. Becker remarked that some Diesel-engine manufacturers say that "any old fuel" will do, while other Diesel manufacturers say that more rigid classifications and specifications should be set up. He thinks the answer probably is a happy medium between these two extremes, and wondered whether the reason Mr. Cummins found no difference between the 25 fuels used in racing might not be because they were carefully selected when sent to him, with the knowledge that they were to be used in racing. It must not be forgotten, he said also, that as the compression ratio of a Diesel engine is raised the field of fuels that can be used satisfactorily in that engine is broadened. This is exactly opposite to what is true for gasoline engines, because, as the compression ratio of a gasoline engine is raised, the field of fuels that will work satisfactorily is narrowed; and this probably has much to do with the differences of opinion as to what fuels can be used satisfactorily in the Diesel engine.

Questions of classification and specification call attention to the fact that more field information is needed in regard to flash point, pour point, carbon residue and the like, Dr. Becker continued. There is not much except the field problem in that regard because definite tests for determining those items are available. Field information is needed as to just what the engine requires. For smooth operation, probably the ignition quality is the most important factor. The Committee is devoting its efforts to developing a method or methods for determining the ignition quality of fuels, Dr. Becker said. Then it proposes to proceed with determination in the field of what ignition characteristics are required. It is important therefore that information be obtained in regard to these characteristics henceforth. With this object in view, the coordinating committee of the A.S.T.M. Technical Committee "C" drew up a rather broad classification consisting of five different fuels. The reason that a rigid ignition-quality was not specified is that field information is desired which will enable the Committee to determine what that quality should be. With that object in view, rather broad limits on cetene number and Diesel Index and critical compression-ratio were suggested.

Dr. Becker stated also that, as the information comes in and as the Committee's work continues, it will become known whether or not a rigid engine-test is needed or whether ignition quality can be determined sufficiently accurately by such indices as Diesel Index and viscosity-gravity constants. His personal opinion is that both may be needed; that, for general field work, it will be found that the latter is sufficient for the time being but that an engine test probably will be required also for research purposes and as a court of last resort.

C. M. Larson discussed the problem of the distribution of Diesel fuels with reference to supplying them for road-building equipment. He said, in part, that two types of fuels seem to be necessary as distributed from a tank station; one for slow-type speed, and another type of a somewhat different distillation range, probably in the second grade, for those in the higher speed-classification. He thinks that the Committee should investigate engine loading, as well, differentiating between full-load and part-load operation.

Regarding oils, the biggest stumbling block today is viscosity, Mr. Larson said. The elimination of grit and dirt is important. He remarked also that the combustion efficiency of automotive Diesel engines is comparatively low and that, if the automotive engine in the motor truck is to be a success, its smoking and odor while idling in traffic must be eliminated because that is one of the reasons for rulings that Diesel-engined trucks cannot run through the main part of a town.

H. D. Hill thinks that the question of fuel specification is one of the greatest importance to the engine manufacturers and to the users of Diesel engines. Unless the purchaser of an engine has some sort of specification under which to order fuel and get what is suitable for his engine, he will not get satisfactory operation, he said. The engine manufacturer is not in a position to write specifications for fuel, and the oil manufacturer does not know what sort of specifications are required for the different classes. The Committee has been at work for a long time and, within the last year or two, it has begun to make some real headway, he remarked, and he urged that it be accorded full cooperation from all those interested.

Mr. Rendel agreed with the various comments, particularly with Dr. Becker's pleas for information regarding field experience. The Committee really needs to know, before it goes too far, just what the importance of ignition quality is under the various circumstances, he said. He feels that the real point of this work is that, during the course of the work in developing a standard method, the Committee will be able to bring out, to the Diesel-engine manufacturers, information that will make the ignition quality unimportant. We certainly don't want the specifications for ignition quality to become a rigid and necessary specification, such as the octane number is for gasoline, he remarked, and it is his hope that as this information develops it will be possible to improve the Diesel engines at the same time so that ignition becomes a relatively unimportant factor. He also agreed with Mr. Larson that the lighter-viscosity fuels are easier to keep clean.

Carl Behn also believes that cleanliness is of the utmost importance, not only in connection with good performance but also from the engine-operators' viewpoint. Mr. Good, of the Chrysler Corp., pointed out that the Otto-cycle-engine combustion-chamber is largely becoming standardized and has standard characteristics, but that no two Diesel combustion-chambers are alike. His company has built a number of small engines and found that, by changing to a different combustion-chamber design, an engine which would run satisfactorily on one grade of oil could be made to run well on another grade of oil. His idea is to standardize on the combustion chamber, which would go a long way toward avoiding trouble.

Mr. Rendel remarked further that it is the idling test that shows up the ignition quality; so, those who are trying to work out a standard service-test should consider, not only the fuel put in and the fuel-consumption curve but also should see what the performance is at half-load and quarter-load and whether the engine runs smoothly while idling.

E. T. Vincent said here that the previous discussors had expressed his views, which broadly amount to stating that Diesel engines will burn almost any fuel. He has used fuel oils ranging from the lightest to some of the heaviest in one engine that is considered in the high-speed range and had equal satisfaction. But, he said, there is undoubtedly great need for specifications that will tell what an oil is; namely, delay period, ignition quality, viscosity and the like. The object should be to get the broadest view possible, rather than to specialize and try to make engines that will operate on one particular grade.

Replying to C. L. Cummins' question on how to get the accelerating or decelerating rate of injection, Mr. Alden drew blackboard diagrams and explained further the details given in his paper.

Answering F. C. Chandler's query regarding how variations in tube length may affect variation in time of delivery, Mr. Alden said that, hydraulically, this system differs very little in its characteristics from those of most of the well-known types of solid-injection fuel-pumps. Tube length is very largely a matter of engine builders' choice; probably some engines, due to combustion-arrangement, would be more sensitive to the start of injection.

E. T. Vincent noted that, in this piece of apparatus, the whole operation of timing individual cylinders to operate at the necessary point of injection relies on the accuracy that is built into the mechanism. Mr. Alden admitted that the unit must be accurate to give accurate results, but said that if all of the by-pass holes are in the same plane and center line and all of the same diameter, they will be closed for the same length of time and, since the duration of closing of these by-pass holes governs the quantity and starting point, if the holes are accurate the job is accurate; but all of the holes are in the one piece, so, it is relatively easy to obtain that accuracy.

Queried by F. E. Watts, as to the general dimensions of the pump and the maximum revolutions at which it operates satisfactorily, Mr. Alden stated that it is about 15 in. long and 12 in. high. The approximate weight is about 36 lb. The pumps have been driven up to 1800 r.p.m. with no difficulty. He said further that 2500 r.p.m. would be the maximum safe operating speed.

Mr. Good remarked that fuel pumps are expensive and said that until they are on a more economical basis he sees no future for them for Diesel engines. This caused Chairman Young to say that Mr. Good, who is looking at the subject from the mass-production standpoint, is hitting a very vital point. In this connection, Joseph Geschelin said that the only consideration as to economics is whether the cost of this unit would be absorbed in the increased economy of operation; so, whatever the cost of the unit may be, he thinks it will not harm the development of the Diesel engine in its present stage.

In conclusion Max Hofmann said that, strictly from a designer's viewpoint, the pump seems to be a very ingenious design, particularly as far as the number of moving parts is concerned. The most interesting feature is that the calibration for the fuel for each cylinder is attained automatically. He has made two tests and said that the field experience is reported as being promising; hence, he thinks the pump will play a large part in the future development of Diesel engines in this country.

Aircraft Transportation Session

Papers at this session: (See page 37, February issue, for digest)—

Operating Requirements for Transport Airplanes—*William Littlewood, Chief Engineer, American Airlines, Inc.*

Designer's and Manufacturer's Viewpoint on the Requirements for Aircraft Intended for Airline Operation—*J. H. Kindelberger, General Aviation Mfg. Corp.*

Supplementary Discussion—*J. L. Atwood, General Aviation Mfg. Corp.*

R. W. AYER said that propeller disc area is important in connection with take-off time and distance, recalling two similar planes, of which one with a higher power-loading had a shorter take-off time than the other, the only explanation being that it had a larger disc area.

Flexibility in motor mountings of rubber is not necessarily desirable, Mr. Ayer said, agreeing with Mr. Littlewood that introduction of some hysteresis is essential in the mounting. Flexibility if carried too far, according to Mr. Ayer, makes the transmission of vibration worse instead of better.

Mr. Littlewood, questioned by Mr. Ayer regarding the importance of wing flaps for deceleration rates on the ground, explained that he was not thinking of flaps as a substitute for brakes, but rather as an added advantage in decreasing loads on brakes, facilitating ground handling, etc.

Mr. Ayer also said that much can be learned by the aircraft industry from the automotive, and expressed his gratitude to automobile manufacturers for availability of experience on buses, trucks, etc. According to Mr. Ayer approximately 50 to 75 per cent of cost for such parts as starters, boosters, steam heating units, fuel pumps and gages, battery chargers, hydraulic brakes, etc., can be saved by cooperation with the automotive industry—with increased reliability for the parts in question.

Questioned by J. J. Curran as to rumors of larger airplanes being in prospect, Mr. Littlewood stated that one manufacturer at present is working on a 48-passenger plane and that a 16-passenger day and night plane also is in the design stage. However, most manufacturers, he said, are waiting for larger engines before proceeding.

J. E. Corey said that insufficient attention is being given at present to ground-time losses and that these largely offset many gains in cruising and top speeds. He suggested that it might be desirable to turn to automobile manufacturers for lessons on landing gear equipment which would enable faster and safer handling on the ground. To this Mr. Littlewood replied that safety demanded that the pilot not maneuver a plane on the ground too fast, considering the danger of hitting a hangar with a wing, etc.

Mr. Corey believes that three engines have an advantage over two or four. He claimed a lower power loss compared to payload with one engine out, for the tri-motor installation. Mr. Littlewood agreed that the theory was correct but said that it didn't work out in practice.

George D. Evans said, in connection with statements on time out for service, that in a recent study he had found that operators were utilizing equipment on an average of only three to six hours out of the day. He wanted to know what operators were doing to boost the service time, estimating that almost 50 per cent of operating costs at present were fixed on a time basis irrespective of time of service per day.

Chairman Wright pointed out that peak loads are just as evident in aircraft operation as in other types of transportation. A controlling influence, he said, is the dictation of scheduled times for air mail by the government, which reduces operating effectiveness for airline operators. The length of time per day that a plane is in service, he said, is not necessarily indicative of the quality of the management in this respect.

Mr. Littlewood, discussing Mr. Kindelberger's half of the Kindelberger-Atwood paper, disagreed as to dangers involved in the use of exhaust type cabin heaters. He said these should be easily serviceable, however, and should preferably be made from unwelded seamless stainless steel tubing.

Mr. Littlewood mentioned the necessity for providing some means to take care of expansion due to temperature of the liquid used in hydraulic retracting mechanisms for landing gears. Mr. Atwood gave some details as to how that is now being handled—largely by introduction in the system of a rubber cup air bell or air dome.

Chairman Wright said that he believed the time had come where it was necessary to increase operating speeds materially. In this respect he agreed with Mr. Littlewood and disagreed with Mr. Kindelberger who had stated that the development was some time off due to lack of economic pressure. Mr. Wright voiced the opinion that the pressure was there, but latent, and just waiting for release when the necessary equipment is made available.

Fuels and Lubricants Session

Papers at this session: (See pages 37 and 38, February issue, for digests)—

Résumé of Research on Oiliness, Conducted on the Sperry-Cammen Adher-O-Scope—*delivered by E. A. Sperry, Jr., Sperry Products, Inc.*

Summary of Replies to Questionnaire of S.A.E. Subcommittee on Oiliness—*prepared by Dr. G. M. Maverick, Standard Oil Development Co.*

Report of Subcommittee of S.A.E. Lubricants Division on Effect of Lubricants on Bearing Metals—*prepared by H. C. Mougey, General Motors Corp., Chairman.*

G. C. BROWN said that the subject of engine lubrication apparently has not received all the consideration that should be accorded it. His experience with bearings leads him to believe that one of the most important points in lubrication is control of temperature. With increasing engine loads, higher temperatures are encountered. Apparently, little attempt has been made to control temperature. A temperature range of 10 deg. is sometimes enough to produce corrosion or make the operation unsuccessful. Insufficient attention also has been given to the amount of oil supplied to the bearings at high speed, this being much less than the attention given in this respect to bearings at the lower speeds.

According to Mr. Brown, reports seem to indicate that a wide difference exists in the compounding agents used in oil and their effect on bearings, the situation being somewhat analogous to the compounding of anti-freeze mixtures. Some compounding agents are all right and others are not. The laboratory work necessary at present is to eliminate the unsatisfactory agents. Tests conducted on the same engine under the same conditions mean one thing but if they are conducted on various engines under various conditions, such as in the method of supplying lubricants, that is another thing. In supplying lubricants to the bearings, pressure seems not to be as important as volume. The volume flowing to the bearing is needed to reduce the temperature, and reducing the temperature may have an influence on reducing the corrosion.

Dr. A. W. Burwell outlined the effect of viscosity as compared with that of oiliness. He said in part that no oils of which we know, even white oils, are lacking in some degree of oiliness. The wedge-shape formed in moving bearings is an aid in sweeping the oil into the bearing and generally is proportioned to the speed. It follows that viscosity is a distinct aid to the power of the bearing to hold a load without metal-to-metal contact at higher viscosities, especially at low speeds.

Dr. Burwell enlarged upon this subject. He stated that the particular oiliness compound which is added must be compatible with the oil used. What we are seeking to do is to clarify this whole situation, he said. Adhesion promotes capillarity. Stability is another important essential, the conception of an ideal oil being to so refine the base oil that the whole will become the most stable mixture possible under circumstances of temperature, pressure and oxidation conditions obtaining in the cracking of all oils, including aircraft engines, and so to resist chemical change without producing a bad effect on the oil; and then to add a compound which will be less likely to have a bad effect and which enhances the film-forming qualities to produce the best effect.

Certain compounds must be avoided on account of the chemical

reactions and these reactions are definitely known, Dr. Burwell continued. On the other hand, the proper kind of oiliness which reduces the internal friction apparently raises the oil stability because of less heat than with high internal friction. There is a critical temperature at which oxidation begins very rapidly, as was stated by J. P. Stewart. He pointed out that there is a narrow band of temperature below which there is very little or no oxidation and above which oxidation takes place very rapidly. In his opinion, Dr. Burwell said, the reason that some engine builders and observers find no advantage in using addition products is mainly because the addition products used did not fit the particular oil and might even cause worse performance and greater heat. Addition compounds frequently are of value; on the other hand, unless they are carefully selected they are worse than valueless.

W. H. Graves said that his company has devoted considerable time to the subject of compound oils and methods of testing them. A number of cars were used in endurance testing, but the company would prefer not to test oils that much to determine whether the oils are suitable; that is, it would dislike to be forced to test and approve or disapprove compounded oils.

B. E. Sibley stated that his company has participated in many hundreds of thousands of miles of road testing with the different types of bearing materials as well as with the different types of lubricants. These showed various results as regards bearing life, not only in weight loss but in the appearance of the bearings. He discussed the relative losses with the several different bearing materials. Apparently, lead is the sensitive constituent in the bearings and undoubtedly is the element worked upon by changes in the oil or by any material added to the oil. Temperature certainly has some effect upon the rate of action—or the life of the bearing—and it was thought that if more oil passed through the bearings the temperature conditions would be improved, and the bearing life would be lengthened.

Mr. Sibley said further that many of the materials which have been worked with do show decided action on the different types of bearing materials, which suggests the conclusion that those who furnish such materials should investigate this subject because the indications are that they are not fully acquainted with the problems of bearing materials and bearing lubrication. He said also that under actual every-day operation the rate of wear is much accelerated, and mentioned that some of the tests upon which wear statements are based do not take into full consideration the every-day operation which, for instance, may mean more frequent starting and cooling down of the engine, and other factors which tend to make the wear greater.

Referring to crankcase-oil temperature, Mr. Sibley noted that this is higher in aircraft than in automobile engines. Of the bearing materials, Mr. Sibley's company has found cadmium to be the least affected by the chemical characteristics of the oil or by the adding of compounds. He suggested that crankcases used in connection with these new bearing materials be drained more frequently. New engines frequently contain grit or abrasive material. He recalled two engines that were intended for tests in which, upon examination, were badly scratched bearings and ringed crankpins; so that new shafts and bearings had to be installed before the engines could be tested. He said further that the harder types of bearings are more sensitive to abrasive materials, and that more frequent draining will help to reduce the maintenance that might otherwise be required.

A report was presented of a résumé of a research on oiliness which was conducted on the Sperry-Cammen Adher-O-Scope by W. C. McIndoe, research chemist, Sperry Products, Inc., Brooklyn, N. Y. In the preface it was stated that in accord with the fact that all the various hypotheses advanced in attempts to explain the causes of "oiliness" involve the ability of oil to wet or cling to bearing surfaces, the research was conducted on the Adher-O-Scope, a machine devised to measure this function. The data obtained were then compared with service performance and other existing ratings of the oils.

Chairman A. L. Beall showed lantern slides of piston rings run with mineral oil for a period of 300 hr. in normal transportation service and piston rings run with compounded oil about 700 hr. in similar service.

C. M. Larson stated that his company had found, in aircraft engines, several instances in which the temperatures were so high that viscosity ceases to be a factor.

R. R. Teetor asked, regarding the effect of oil temperature on the deterioration of bearings, at what temperature the critical point appears and what condition of the oil affects the temperature of the critical point at which deterioration becomes more rapid. To this Mr. Stewart replied that, with some products, the temperature is a very critical matter and that a very small increase in temperature may make a large change in the amount of gum formation. This varies with different oils; and the temperature and rate of change varies with the oil, but primarily depends on the oil.

Passenger-Car Brake Session

Papers at this session: (See page 38, February issue, for digests)—

Hydraulic Brake Actuation—*Burns Dick, Wagner Electric Corp.*

Brake Drum and Lining Development—*Chris Bockius, Raybestos-Manhattan, Inc., and J. Harold Hunt, Motor Wheel Corp.*

J. A. ANGLADA cited an instance in which he applied the brakes on an air-cooled car in the mountains and found that the pedal went to the floor without any effect on the brake. He asked what kind of brake lining will stop a car with the minimum amount of pedal pressure and what kind of lining will last the greatest length of time. Mr. Dick replied that it is quite necessary to protect the hydraulic system from excessive heat when used with an air-cooled engine. The possibilities for trouble from that source are many; they are greater than on the average water-cooled-engine car. It is also advisable to locate the compensator and the pipe lines as far away as possible from the exhaust lines; in general, precautions are necessary to prevent heating of the fluid lines.

M. C. Horine criticised the number of adjustments employed on the hydraulic brakes, but Mr. Dick replied that about half of them are intended to be manufacturing adjustments and are usually not often disturbed. The human figure depicted in Fig. 5 of the paper and the curves in Figs. 6 and 7 were used in working out a project intended to determine how much energizing should be used. This was a much greater problem than was expected, but it did produce an original point of view and method of approach.

R. F. Berg used the blackboard in discussing Mr. Bockius's paper to show a curve illustrating approximately the rates of wear of flection materials with reference to temperature. Chemical laboratories of every company today, I am sure, he said, are engaged in attempting to extend this curve further as temperatures rise, and we all hope to get eventually a material whose rate of wear is a straight line with respect to temperature ranges.

As to the broad question of what the ideal brake lining is, Mr. Bockius said that this cannot be answered. Even when the brake drum and brake linings are the best we know how to produce there might be differences in brake shoes and how they perform under varying temperature conditions of the brake mechanism. Without mentioning any specific brake, he continued, the ideal lining is one that does not disclose any apparent difficulty in performance to the operator of an ideal car and that functions under a wide range of driving conditions. It is not always possible to say that all the difficulties that one encounters in the performance of brakes on the road are due to the parts of the brakes themselves. With a very durable lining material it is very apt to be subject to a condition of surface contamination which will make the apparent characteristics of the lining vary widely from the original conditions. This is very apparent in very mild brake applications, such as with a very careful driver who very seldom applies his brakes for more than an extremely moderate stop. I have examined the linings of such cars and found them covered in quite a few instances with a film of material which is not at all related to the flection material of the lining, he concluded.

Mr. Anglada asked whether it is advisable to use a soft lining which will permit of readily controllable stops with a minimum pedal pressure with frequent renewals of lining, or whether it is preferable to use a harder lining which requires a more severe pressure of the brake lever to make a lining wear longer. Mr. Bockius replied that frictional characteristics have no bearing, as he sees it, on whether the material is dense or whether it is compressible in characteristic. One may have a low frictional characteristic in low compressible material or, conversely, a high frictional characteristic. With a dense material the pedal performance, as pointed out in Mr. Dick's paper, is a matter of the characteristics of the brake. Density of the lining will have an influence toward loss of the brake under high pressure and high rate of stopping.

Mr. Hunter, of the B. F. Goodrich Co., discussed airplane brakes. He hopes that the Society will investigate the standards suitable for airplane brakes. Mr. Bockius replied that he did not mean to belittle the severity of the service required of airplane brakes. He remarked that the brake drums of a passenger car operating in traffic often become very hot. In his opinion the hardest test to meet in brake performance is a series of 45 m.p.h. stops. The severity of the test lies not in high-speed stops but in a series of what might be termed moderate-speed stops.

Herbert Chase asked when a hard lining is desirable and when a

soft one is; also, how linings compare at present, as against two or three years ago, in respect to their resistance to water absorption. Mr. Bockius said that the tendency in recent years has been to make the lining practically incompressible. The soft lining is practically obsolete today, he continued, for the reason that the pedal ratio has been carried to such a point that a compressible lining probably would hold its adjustment for so short a period that people would not want to use that type of material. He said further that water absorption was a larger factor before harder materials of the type he referred to were available. The structure was more or less open and the amount of water the structure would hold was rather greater. As unit intensity is approached, the amount of space that water could occupy if the material is emersed is reduced. Most of the linings on the market today, he said, are as close to unit intensity as seems desirable. He thinks that water absorption is not as great as it was three to five years ago. As to water absorption in relation to brake performance when the brakes are wet, that has reference to the frictional characteristics of the surfaces when they become wet. That is dependent upon the type of material and the material itself. We make friction tests on all our new materials that are in the process of development to determine their characteristics, he remarked, but so far we have never been able to take any particular material and say that it will be the ideal lining for performance when wet. The condition can be improved by a juggling of the ingredients.

A. W. Scarratt said that he thinks the motor truck presents probably the hardest braking problem. H. K. Gandelot discussed airplane brakes at some length, and so also did D. P. Forbes. The latter commented on the airplane problem because it has a certain bearing on extreme operating conditions.

J. H. Hunt said, regarding what effect wheel design has on cooling of the drum, that it has some effect but not enough to be really serious. The appearance of the wheel is being considered more seriously than the design effect on the cooling of the drum. A wire wheel with a small hub would give more cooling effect on the drum, but it has not been proved that there is enough differentiation to constitute a serious factor, because the appearance is so much more desired than the effect of the cooling.

Passenger-Car Engine Session

***Papers at this session:** (See page 38, February issue, for digests)—*

Engine Flame Temperatures Vary with Knock and with Position in the Combustion Chamber—*Gerald M. Rassweiler and Lloyd Withrow, Research Division, General Motors Corp.*

Flame Movement and Pressure Development in Gasoline Engines—*Clarke C. Minter, consulting chemist.* (Paper published in full, pages 89 to 94, this issue)

CHARLES F. MARVIN, JR., and Frank W. Caldwell, confined their prepared discussion to the references (made at the end of the Rassweiler-Withrow paper) to their own experiments, saying: "The authors of the discussed paper attribute the rise in temperature of the inflamed gases near the spark-plug to the compression of these gases as the pressure in the cylinder increases, and suggest that the coincident rise in the total radiation, which we found in experiments at the Bureau, is due simply to this temperature rise. However, it must be realized that the total radiation is a function of the temperature, not of the inert constituents of the charge, but particularly of the CO_2 and H_2O, and that it is affected by the concentration of these substances and perhaps their "chemical condition" as well as their temperature.

"It seems reasonable to suppose that H_2O and CO_2 are formed by combustion at temperatures far above those attained by inert portions of the charge (including any sodium vapor), that in this newly formed state they radiate most intensely, but that they are rapidly cooled and their potency as radiators diminished as they are called upon to heat about three times their volume of inert constituents. Thus, if the final products H_2O and CO_2 were suddenly formed in large quantities within a narrow flame front, we would expect to find there a zone of very intense radiation followed by a region in which the recompression of the charge, while raising the average temperature level, would only partially offset the cooling of H_2O and CO_2 as they transferred heat to the inert materials. Since the observed rise in radiation was not sudden, but gradual and long continued after the arrival of visible flame, we infer that the formation of H_2O and CO_2 is also gradual, although we point out in our paper that the recompression and the movement of more recently burned charge into the neighborhood of the spark-plug probably prolongs the rise in radiation in this region.

"In connection with the possibility of burning within the cavity beneath a window, the small spacing collar below each window was made of nickel and designed to promote turbulence and facilitate rapid cooling within the cavity. That it accomplished this purpose with some success was evidenced by the fact that the fluorite windows cracked, presumably due to heating, when the spacer was removed and the fluorite placed close to the combustion chamber.

"In the normal run the flame arrives under the last window at about the time of maximum pressure. It seems unlikely that it would propagate far into the cavity against the stream of gases which flows outward at an increasing rate as the pressure in the cylinder drops. Even in the knocking run, where the flame probably is driven into the cavity by the sharp rise in pressure accompanying the knock, there is little evidence of prolonged burning in the cavity. While admitting that burning in the cavity may influence the results and introduce some uncertainty in their interpretation, we do not believe that this burning dominates the observations to the extent suggested."

A. E. Hershey and Prof. R. F. Paton said in part, in their prepared discussion of the Rassweiler-Withrow paper: "By no means the least valuable aspect of the authors' extensive data on engine combustion is that the major portion has been obtained with the same engine under strictly comparable conditions. The factors affecting combustion in any one engine are so numerous and difficult to control that the reproduction of experimental conditions is one of the most annoying problems confronting the investigator. This difficulty is increased manifold when it becomes necessary to correlate data taken by several investigators on different engines and under different conditions. Hence, while the authors' well-known investigations of flame movement, pressure fluctuations, and emission and absorption spectra are each in themselves valuable, collectively with the present investigation of temperature, they constitute the outstanding contribution to the study of combustion in an engine.

"Of particular interest is that portion of the paper dealing with the temperature gradient existing in the gases in the combustion space. Such temperature gradients have been the basis of speculation for some time but their actual existence and magnitude have now been determined. However, the important thing is not that they exist, but that they are relatively small.

"The criticism of thermodynamic calculations based on temperatures obtained by line-reversal measurements does not appear to be serious. As the authors state, Griffith and Awberry have made temperature measurements with two stationary flames at different temperatures in the optical path. They report that with the lower-temperature flame adjacent to the spectroscope the observed temperature falls between the two flame temperatures and approximates the arithmetical mean of the two. Hence, in determining flame temperatures in an engine, if the flame is advancing along the optical path within the region of low temperature adjacent to the spectroscope, the observed values should be fairly representative of the average temperature throughout the region. Thus, line-reversal measurements are apparently the result of an effect integrated throughout a region of the combustion chamber.

"The discussion of temperature and luminosity is also of considerable interest. One of the most surprising results of the authors' investigation is the very slight difference in temperature of the gases in the knocking zone under knocking and non-knocking conditions.

"An increase in radiation intensity without a corresponding increase in temperature as measured by line reversal would seem to be convincing evidence that the excitation of the sodium atoms in the flame is thermal and hence that temperature measurements made by line reversal are independent of luminescence effects."

Bernard Lewis, of the Bureau of Mines, submitted written discussion in which he congratulated Dr. Rassweiler and Dr. Withrow on the conspicuous success which has marked their researches on the explosion process in the gas engine, of which their present report is but a part. He stated that there is no doubt but that their work has markedly advanced our understanding of engine phenomena. The data of this discussion have not yet been released for publication.

Guenther von Elbe amplified the arguments of Dr. Lewis, as did also Dr. Rassweiler. The latter said also that the difference between our method of determining flame temperatures and that of Hershey and Paton is that we separated the emission temperatures, the gases burned first and last. They, in making the measurement, passed their beam of light along the length of the combustion chamber; so, the result is in a sense obtained across the combustion space. In this respect their work differs from ours and it is also of interest to point out that they had a somewhat different type of chamber, an overhead-valve instead of an L-head type, and did not observe any indications of the temperature gradient in the combustion chamber. It is questioned if

this was present. Therefore, comparison of the theoretical work is of interest.

R. N. Janeway complimented Mr. Minter because of the unusual insight he has shown in connection with the compression problem, as well as for his investigation of the principle of volume distribution. Some of the points covered by Mr. Janeway in commenting on Mr. Minter's were as follows: "The problem of determining engine smoothness by combustion-chamber design has two main requisites; first, the prediction, which is reasonably accurate, of pressure-time character of burning and second, the interpretation of that characteristic in terms of engine roughness. Clearly, the variation in flame velocity is a vital factor in determining the pressure-time characteristic. The method that I actually used to form quantitative relationship was to take actual indicator cards from a number of different chambers and determine the constant used, to get agreement between predicted and actual curves.

"Regardless of whether the relationship so derived as to flame velocity is strictly true as to flame velocity itself, we have in that method of attack a compensation for errors involved in assumption, so that the overall result, which is the thing we are really interested in from a practical standpoint, can be accepted with confidence. In other words, we have established a method by which we can determine a pressure-time characteristic that will agree so far as the important aspects of the curves that actually are obtained from the engine are concerned. To me it is the important thing, and the only logical method that can be justified in a problem of this kind." Mr. Janeway also discussed at length other points in Mr. Minter's paper.

Alex Taub described and commented upon his company's practice in eliminating as much as possible of the confusion pertaining to combustion-chamber design. He showed in this connection lantern slides of a machine for cutting plaster forms to determine what the volume distribution is.

Fuels and Lubricants Session

Papers at this session: (See page 39, February issue, for digests)—

Report of Cooperative Fuel Research Committee on 1934 Detonation Road Tests—*C. B. Veal, Secretary, C.F.R. Committee; presented at the meeting by H. W. Best, Yale University.*

The Lubricant Requirements of Automotive Worm Gearing—*C. H. Schlesman, Socony-Vacuum Oil Co., Inc.*

IN prepared discussion Roland V. Hutchinson referred to Fig. 2 of Dr. C. H. Schlesman's paper, stating that the efficiencies reported are appreciably lower than has been his experience with other axles of comparable size and ratio, though the shapes of the curves check with his experience. Referring to Fig. 1 of the paper, he stated that the term "churning losses" seems to have been confused with the more exact term "loss when transmitting zero power," which latter includes the former. If there were no losses existing, he continued, then the input torque on the wormshaft would equal wormshaft thrust times center distance; hence he has found it more convenient to analyze in terms of lost worm-thrust, to setting-up conditions plus that due to pure churning losses.

Mr. Neely congratulated Dr. Schlesman on his work and said in part that lubricants devised for extreme-pressure lubrication seem invariably to find their way into worm gears. He thinks that the paper emphasizes the importance of extreme-pressure lubricants as connected with worm gears.

Dr. H. C. Dickinson remarked: "One point that is worth considering is that Dr. Schlesman's paper brings out different characteristics of lubricants which we have to consider, and which we ought to keep in mind in order to clarify the problem; (*a*) the tendency to seizure, (*b*) the rate of wear under normal conditions, and (*c*) the ability to stay in place and keep on operating. These are not related to each other in any way. One cannot say that one lubricant will protect from seizure or will wear better than another; so, in the entire consideration of the problem, it is necessary to keep in mind these three elements which are independent of each other, and not draw any conclusions based on one alone.

Dr. Schlesman thanked Dr. Dickinson for emphasizing the foregoing. These runs were made at constant temperatures, he said, and then applied them to the several fields. In the case of bearing wear, many data are necessary.

As a sequel to the Uniontown Tests, Donald Brooks presented a report on two lines of detonation research which have been carried on at the National Bureau of Standards. The first was a study of the variability of cars of one make with respect to road rating of fuels. The second line of work was a study of the sensitivity of fuels to changes in the apparent mixture temperature, particularly with a view to determining whether Research-Method ratings could be duplicated by proper choice of apparent mixture temperature. However, the data of the report have not yet been released for publication.

In the prepared discussion presented by C. S. Hebl, he said that mention was made in the C.F.R. Report of the severity factors of automobiles. We have found this factor to be a useful tool in our work on detonation and wish particularly to draw this to the attention of automotive engineers, since an engine designed for a low severity-factor can use to greater advantage the high research octane number fuels often supplied. However, before citing three examples of its application, certain points in connection with its calculation need clarifying. It is obvious that, since the depreciation on most fuels is not much greater than the errors of testing, the severity ratios obtained from the ratings on single fuels are, therefore, very inconsistent. However, the significance and reliability of the severity factor increases in proportion to the fuel sensitivity. Reliable values of the severity factor can be obtained by rating several sensitive fuels and adding together the depreciations obtained on the road and dividing the sum by the similar sum of the depreciations obtained in the A.S.T.M. test on the same fuels, the depreciation in both cases being measured from the research-method ratings.

Mr. Hebl gave an example of the computation of the severity factor, from tests made in Car No. 15 at Uniontown. Continuing, he said that the importance of rating the same fuels under each test condition is obvious. The severity factor as computed will be found useful for analyzing data from tests carried out in the past; for instance, the results presented to the C.F.R. Committee by the Ethyl Gasoline Corp. early in 1932, and the Uniontown data. He then gave three examples of its use in connection with the tests.

Mr. Hubner, in discussing the report, dealt with the detonation of the fuels and showed a lantern slide that compared the results in 1932 and 1934 on two fuels of the same knock-rating characteristics.

J. M. Campbell submitted written discussion. He stated in part that several speakers have discussed the variations in knock ratings that are observed between different makes of cars and even between different cars of the same make. It might be pointed out that the magnitude of these variations may not be so disturbing as it may seem at first sight when it is recognized that these variations in knock rating from one car to another are all measured with respect to standard reference fuels A-3 and C-8 whose knocking characteristics are somewhat unlike those of the average commercial gasoline. Although these reference fuels have certain desirable properties, particularly from the standpoint of stability in storage, their sensitivity to changes in engine conditions is such that they present a somewhat magnified picture of variations in knock ratings between different cars. On the other hand, if a representative commercial gasoline, such as is of necessity employed in the development of car engines, were used as a reference fuel, the variations in knocking ratings between different cars might be expected to be very much reduced. As was pointed out in the C.F.R. Report, knock ratings change with engine conditions because different fuels have different rates of change of knocking tendency with changes in engine conditions.

Mr. Campbell showed two curve charts of extreme cases of how knocking tendency may vary with engine conditions. He remarked that it seems quite probable that these two factors, mixture ratio and engine speed, contribute very largely to the variations in knock ratings among different cars inasmuch as road ratings are made over a wide range of mixture ratios and engine speeds. Incidentally, with respect to each of these two variables, the reference fuel appears to be the more "sensitive" fuel. Variations in knock ratings with respect to the reference fuels naturally imply that some cars rate fuels lower than others. This has given rise to the concept of engine "severity" and "depreciation" of antiknock value in service tests. As a matter of fact, the data upon which these concepts are based do not indicate whether it is the average gasoline that "depreciates" or the reference fuel that "appreciates." The solution of the problem of designing engines so that they will not "depreciate" fuels appears to depend upon the reference fuels chosen and upon the engine conditions with respect to which "depreciation" is measured.

In conclusion, Mr. Campbell said that since engines are actually developed to use conventional types of gasolines rather than to use fuels similar to reference fuels A-3 and C-8, it may be preferable to choose a more representative type of gasoline for a reference fuel for measuring knocking characteristics. With such a reference fuel the matter of "appreciation" and "depreciation" of fuels in service would be expected to be reduced to insignificance for the large majority of commercial gasolines and only a few exceptional types of fuels would show appreciable amounts of either "appreciation" or "depreciation." Very

important to note, however, is the fact that the knock-testing procedure which would correlate all types of fuel with road performance would not be affected by such a change in reference fuels.

To give a clearer picture of the difference between the cars used on tests and results in the laboratories of the motor methods on the fuels, a chart prepared by Mr. McGregor was shown and commented upon by Mr. Neely which represented the depreciation of rating of any given fuel by a motor method between the laboratory and in different cars shown. He said it would be noted thereon that variations up to five octane numbers have been obtained by rating the fuels on the different laboratory tests and that the variations are as high as ten octane numbers between engines. The wide differences indicate that further research work is desirable in order to arrive at a better correlation between laboratory and road tests.

Production Session

Papers at this session: (See page 39, February Issue, for digests)—

What Is Surface Finish and How Can It Be Measured and Specified?—*E. J. Abbott, Research Physicist, University of Michigan.*
(Paper published in full, pages 112 to 116, this issue)

Surface Integrity and Dynamic Strength—*A. V. de Forest, Associate Professor, Mechanical Engineering, Massachusetts Institute of Technology.*

1934 Developments in Cam and Cylindrical Grinding—*Howard W. Dunbar, Manager, Grinding Machine Division, Norton Co.*

Single Point Boring of Cylinders and Diamond Turning of Pistons—*W. F. Wise, Ex-Cell-O Aircraft & Tool Corp.*

Modern Resistance Welding in the Automobile Industry—*P. W. Fassler, President, P. W. Fassler & Co.*

I. J. SNADER answered questions asked in connection with the paper by Mr. Wise, the latter having been called away from the session before its completion. In turning the particular piston illustrated in the paper, Mr. Snader stated, a diamond had been used because it is about the only tool capable of performing the particular operation due to the frail structure of the piston. Any other tool would push the piston out of shape, so that it would be outside of specified tolerances, he said.

The cost of the diamond tools used on this operation, Mr. Snader continued, was approximately $25 apiece, while tungsten carbide tools for cylinder boring operation, while much heavier would cost approximately $6 or $7.

Use of the diamond results in a very much higher polished finish than does use of tungsten carbide tools on the same material, according to Mr. Snader.

Questioned as to how deep the groove would be if, in diamond boring the cylinder hole, the tool were not withdrawn from the surface, Mr. Snader replied that there would be a very minute scratch. Its depth, he said, "would not be more than the tool mark, which would be from the top of the tool threads to the bottom." It may not be entirely necessary in all cases to withdraw the tool, Mr. Snader said, because the honing would take out the scratch.

One question asked following Mr. Wise's paper was:

"Have you ever tried a plug that is as long as the bore, into a cylinder bore that had been reamed in the usual way and one into a cylinder bore that had been bored as stated by Mr. Wise in his paper; if so, how much smaller than the respective bores did the plugs have to be made in order to get them through the bore?"

Mr. Snader replied that he had tried plugs as described in bores as reamed in the regular way and found that they had to be made considerably smaller than the bore in order to get them in, due to irregularities of the reamed bore, but that he had not as yet tried one into a bore of a cylinder as bored on an Ex-Cell-O machine. Subsequently, Mr. Snader made the suggested test. About the results he writes as follows:

"Two bores checked after conventional reaming, and before honing, required the plug to be 0.0022 and 0.0035 smaller than the mean diameter of the respective bores before it would enter the full length of the bores."

Mr. Dunbar stated that a "mirror" finish is not necessarily a smooth finish, and that a lot depends on the preparation of the material under the surface.

Asked by Joseph Geschelin about the chances of using a profilograph for setting up production standards, Dr. Abbott said that there is only one instrument now in existence, although the second one is on the drawing board. Because this model cost between $7,000 and $10,000 before final completion, Dr. Abbott thinks it better to develop special purpose instruments for particular jobs. "If anyone has problems of finish," he suggested, "we feel sure they can be solved; but as for general purpose instruments—we don't think that is the economical way to approach the matter." The present instrument is available for setting up a standard of finish, however, Dr. Abbott stated.

The best way to use the profilograph records in production, Dr. Abbott said, would be to determine the relative roughness of a series of examples of grinding. If you had a set of standards against which you could hold your product, you could get an accurate check on finish, he said. However, if you want to compare one operation against another, the only way is to have profilographs made of the specimens prepared.

Dr. Abbott said that no definite check had yet been made as to whether or not there is a definite relation between reflective surface and profilograph.

H. D. Allee agreed with Dr. Abbott that the finger nail and lead pencil method of checking is crude, but stated that a microscopic examination of specimens with a definitely located lamp placed at the exact distance from the work and uniformly illuminated does give a very good means for checking finish.

"At the Bantam Ball Bearing Co.," Mr. Allee said in part, "Bethel Player lapping giving either a satin finish or a lustre finish is compared with lime tumbling using either Venetian lime or Levigated Alumna very readily and accurately with a microscope, and this method of examination has for the past several years produced satisfactory results."

Discussion involving both Mr. Wise and Dr. Abbott developed regarding the relative advantages of smooth as compared to slightly rough cylinder bores in relation to oil consumption during the "break-in."

O. E. Kurt asked "What is the relation of roughness to wear?" To this Dr. Abbott replied that no one has been able to find out previously because there was no adequate means available of actually measuring "roughness."

The real purpose of putting a finer finish on, Dr. Abbott said, is to improve wear and lubrication. He believes that smoother finishes are better from this standpoint.

At the request of Chairman W. H. McCoy, Mr. Dunbar described a new type of grinding machine recently developed by the Norton Co., but which is not yet ready to offer to production engineers. It is the first new development in this field since the introduction of centerless grinding, Mr. Dunbar said, and works on an entirely new principle. He used lantern slides to illustrate and clarify his description of this experimental process.

Called "Conjugate principle of grinding," the process is adapted to the finishing of non-cylindrical surfaces on fixed centers. Thus, with this machine, all the cams of a camshaft can be ground simultaneously, with all grinding wheels on one spindle and the camshaft on fixed centers. This is achieved by use of eccentrically shaped grinding wheels, the eccentricity or shape being determined by the shape of the cam.

In discussion of Mr. de Forest's paper, W. J. Cumming said that 75 per cent of the fatigue failures in service on vehicles of the Surface Transportation Corp. of New York had been directly traced to surface imperfections. He added that parts had even been found with surface cracks resulting from heat treatment—parts supposedly of highest quality.

W. B. Hurley, discussing Mr. Fassler's paper, emphasized the fact that if you can get a power factor up, it does not take as big a welder to do a certain job. "You can get the automobile manufacturer interested in power factor because he can use smaller distribution lines and smaller main power lines and reduce the voltage of his welding," Mr. Hurley continued. "The higher the plant's power factor, the more capacity we have with the proper amount of current. All progressive power companies would be glad to cooperate with welding manufacturers to work out means to improve the power factor of welding machines."

Commenting on this same point, Mr. Fassler said that the electrical viewpoint is the first thing to be considered in building a welding machine.

Further discussion developed the immense importance of the power factor in connection with construction and use of welding machines.

New Members Qualified

These applicants who have qualified for admission to the Society have been welcomed into membership between Jan. 10, 1935, and Feb. 10, 1935.

The various grades of membership are indicated by: (M) Member; (A) Associate Member; (J) Junior; (Aff.) Affiliate Member; (SM) Service Member; (FM) Foreign Member.

BOYLE, CLETE L. (M) president, Industrial Chemical Products Co., 3777 Bellevue, Detroit.

CHAPMAN, WM. H. (M) supervisor, methods and equipment division, Hyatt Bearings Division, General Motors Corp., Harrison, N. J.; (mail) 23 Carolin Road, Montclair, N. J.

CLENDENEN, JOHN C. (A) salesman, Standard Oil Co. of California, Exchange Building, Seattle, Wash.; (mail) 711 North 60th Street.

COLE, ROBERT ALEXANDER (J) test engineer, Wright Aeronautical Corp., 1120 East 19th Street, Paterson, N. J.

CONNELL, E. B. (A) supervisor, lubricating sales, Union Oil Co. of California, 617 West Seventh Street, Los Angeles.

DUNHAM, ROBERT E. (J) research engineer, Conewango Refining Co., Warren, Pa.

ELFES, DONALD B. (J) test inspector, experimental engineering division, Packard Motor Car Co., Detroit; (mail) 4134 Dickerson Avenue.

ELLIS, ROBERT E. (M) assistant manager, aviation department, Standard Oil Co. of N. J., 26 Broadway, New York City.

ENGSTROM, CARL (J) laboratory worker, U. S. Rubber Products, Inc., Detroit; (mail) 2593 Lenox Avenue.

FICK, A. L. J. M. (F M) governing supervisor, public automotive transport, Wilhelminapark 16, Breda, Holland.

FLETEMEYER, RAYMOND E. (M) president, manager, Stewart Motor Truck Co., Inc., 4901 Liberty Avenue, Pittsburgh, Pa.; (mail) 2928 Fernwald Road, Square Hill.

GRUBER, FOSTER M. (J) test engineer, Wright Aeronautical Corp., Paterson, N. J.

HAINES, JOHN F. (J) assistant experimental engineer (aircraft engine), Steel Products Engrg. Co., 1060 West Columbia Street, Springfield, Ohio; (mail) 815 North Fountain Avenue.

KENNEDY, HARVEY T. (M) physical chemist, Gulf Research & Development Corp., Post Office Box 2038, Pittsburgh, Pa.

LINDSAY, GEORGE EDWARD (A) industrial sales engineer, Exide Batteries of Canada, Ltd., 153 Dufferin Street, Toronto, Ontario, Canada.

LISTON, JOSEPH (M) assistant professor, mechanical engineering, University of Oklahoma, College of Engineering, Norman, Okla.

MCMAHAN, RAYMOND GLEN (A) power prover engineer, Cities Service Oil Co., 3200 South Western Avenue, Chicago; (mail) 2120 Meridian Street, Anderson, Ind.

MILLER, ROBERT L. (M) automotive safety engineer, Aetna Insurance Co. and Affiliated Companies, 100 William Street, New York City; (mail) 713 First Street, Westfield, N. J.

MORRISON, MALCOLM C. (M) assistant traffic manager, Dairymen's League Co-operative Association, Inc., 11 West 42nd Street, New York City.

OELSCHLAGER, W. R. (A) general foreman, International Harvester Co., Milwaukee; (mail) 1611 South 76th Street, West Allis, Wis.

OLANDER, ALDEN C. (J) sales promotion, Studebaker Sales Corp., South Bend, Ind.

PAPPAS, COSTAS ERNEST (J) 9-34 - 122nd Street, College Point, L. I., N. Y.

PATCHETT, GEORGE WILLIAM (F M) chief designer, Zbrojovka Ing. F., Janecek, Praha, Nusle 2, C.S.R., Czechoslovakia; (mail) U. Druhe Baterie c10, Stresovice c764, Prague 18, Czechoslovakia.

PIVARSKI, SAMUEL (J) detail draftsman, Fisher Body, Detroit Division, Plant 27, General Motors Building, Detroit; (mail) 3051 Algonquin.

REGGIO, FERDINANDO CARLO (F M) experimental engineer, Compagnie Lilloise de Moteurs, 71 Rue Marius Aufan, Levallois, Seine, France; (mail) 17 Rue Jean-Baptiste Dumas, Paris, France.

SALTER, TOM (J) engineer, Cessna Aircraft Co., Wichita, Kans.; (mail) 337 North Holyoke.

SEYFFARDT, ALFRED LODEWJK WITTEM, 1st Lieut. (F M) Royal Army, Motor Traction, Haarlem, Holland; (mail) Vijenbansche Kade 2, Delft, Holland.

SKLOVSKY, MAX (M) chief engineer, Deere & Co., Moline, Ill.

SNEED, RICHARD B. (J) graduate laboratory assistant, University of Oklahoma, Mechanical Engineering School, Norman, Okla.

SUREAU, JOHN DELANY (A) general storekeeper, Third Avenue Railway System, 2396 Third Avenue, New York City.

WAGNER, CLAUDE M. (A) service superintendent, Kings County Buick, Inc., 60 Empire Boulevard, Brooklyn, N. Y.; (mail) 6 Sunnyside Avenue, Hempstead, L. I., N. Y.

ZENGER, HERBERT (A) general manager, Stevens Corp., 1411 North West Flanders Street, Portland, Ore.

ZSUFFA, LESLIE F. (J) maintenance, United Parcel Service, 331 East 38th Street, New York City; (mail) 7513-97th Avenue, Woodhaven, L. I., N. Y.

Applications Received

The applications for membership received between Jan. 15, 1935, and Feb. 15, 1935, are listed herewith. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ANDREWS, WILLIAM GEORGE, manager, motor department, Shell-Mex & B. P. Ltd., London, England.

ANDERSON, A. G., International Harvester Co., Chicago.

APPELT, HENRY C., test engineer, Muskegon Piston Ring Co., Muskegon, Mich.

BLAIR, THOMAS S., sales engineer, H. L. Doherty & Co., New York City.

BONEHAM, JOHN, managing director, Boneham & Turner Ltd., Mansfield, England.

BROWER, GILBERT K., chief chemist, American Airlines, Inc., Chicago.

BUDZIEN, HUGO F., designer, Diesel engineer, Fairbanks Morse & Co., Beloit, Wis.

CENDER, ELVIN O., designing engineer, Gra-Jen Equipment Co., New York City.

CHENEY, SEYMOUR JEROME, draftsman, Bendix Products Corp., Stromberg Division, South Bend, Ind.

CONINE, ROBERT C., writer, *The Oil & Gas Journal*, Oil City, Pa.

DAVISSON, GORDON E., tool designer, International Harvester Co., Chicago.

DOWNEY, GEORGE A., assistant manager, George Lawrence, Inc., Cambridge, Mass.

DOWNIE, GEORGE SIM, manager, George Downie, Port Dover, Ont., Canada.

EBNER, EMIL E., superintendent, Quaker State Oil Refining Corp., Emlenton, Pa.

FORKER, LEE R., assistant department manager, Quaker State Oil Refining Co., Oil City, Pa.

FRIBERG, ALGER ROBERT, owner, A. R. Friberg Co., Los Angeles, Cal.

GIBSON, R. P., manager, Detroit office, The Weatherhead Co., Cleveland.

HALL, HARRY, Diesel designer, Fairbanks Morse & Co., Beloit, Wis.

HARRISON, JOHN, JR., president, Charles F. Kellom & Co., Inc., Holmesburg Station, Philadelphia.

HARTWELL, SAMUEL A., JR., service division manager, Pennsylvania Grade Crude Oil Association, Oil City, Pa.

HEALY, DONALD MITCHELL, chief engineer, Triumph Co. Ltd., Coventry, England.

HEINTZ, RALPH M., president, general manager, Heintz & Kaufman, Ltd., San Francisco.

HILEMAN, PAUL D., sales engineer, Thompson Products, Inc., Cleveland.

HOLLERITH, OTTO, test engineer, Wright Aeronautical Corp., Paterson, N. J.

HORTON, ERWIN C., chief engineer, Trico Products Corp., Buffalo, N. Y.

JANSON, CURT E., chief mechanic, Chicago Board of Underwriters, Chicago.

JOHNSON, GLENN D., chief engineer, MacClatchie Mfg. Co., Compton, Cal.

KELLY, CHARLES IGNATIUS, chief chemist, Herbert Green & Co. Ltd., London, England.

KOSIYAKARCH, CAPTAIN LUANG KARA, superintendent of aircraft factory, Royal Siamese Aeronautical Service, Bangkok, Siam.

LATIMER, WILLIAM JAMES, JR., Lieutenant, U. S. Army, Watertown Arsenal, Mass.

LEISE, FRED, Yoder, Colo.

LUND, CHARLES R., automotive engineer, The American Oil Co., Pittsburgh, Pa.

MARKUS, ALFRED, treasurer and manager, Markus Motor Service, Inc., Lowell, Mass.

MCCLUER, WILBERT B., chemical engineer, Kendall Refining Co., Bradford, Pa.

MINETT, IRVING J., experimental boxing, Chrysler Export Corp., Detroit.

(Continued on page 40)

Behind the Scenes With

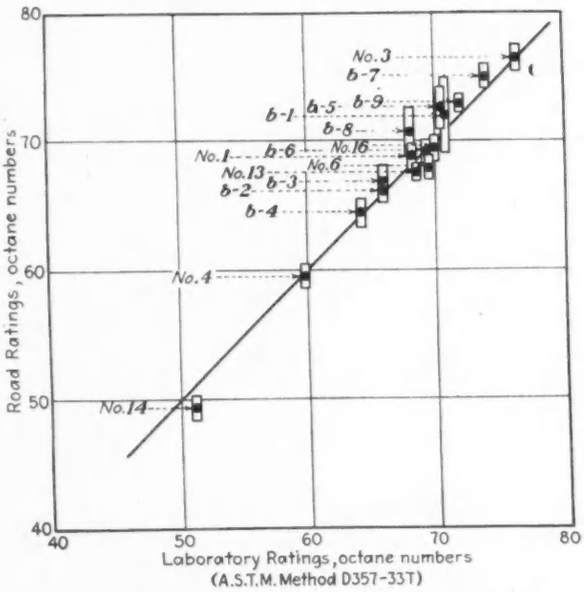
1934 Detonation Road Tests

A PRELIMINARY report covering part of results of the 1934 Detonation Road Tests of the Cooperative Fuel Research Committee was presented by C. B. Veal, secretary of the Committee, at an American Petroleum Institute meeting, held last November in Dallas. In his discussion of results in this report (which was preprinted by the American Petroleum Institute), Mr. Veal goes into laboratory ratings, hill ratings, level road ratings, cross-country ratings, detonation meter ratings and special reference fuels with appropriate tabulations to accompany each summary.

In his discussion of correlation he says:

"The first objective of the 1934 detonation road tests was to check the validity of correlation between road knock ratings and laboratory knock ratings by the C.F.R. motor method (A.S.T.M. designation D357-33T).

"A comparison of the hill-road ratings of the test fuels with the laboratory ratings obtained by the A.S.T.M. and research methods has been tabulated. The maximum variations from the A.S.T.M. method, which occurred in the cases of fuels No. b-8 and 14, are 2.7 and — 1.9 octane numbers, respectively; and the algebraic average variation for all fuels is 0.36 octane number. The degree of correlation between ratings by the A.S.T.M. method and hill-road ratings is shown in Fig. 2. In this it will be noted that the 45-deg. line illustrates perfect correlation. The points are the average road ratings for each test fuel as given in Table 6, and the height of the vertical rectangles represents the average spread of the road ratings. These spreads illustrate the difficulty involved in attempting to develop a laboratory method which will give better correlation until they can be reduced. Analysis of the data mathematically or graphically, as in Fig. 2, indicates that the correlation between the present A.S.T.M. method and the Uniontown road-test data is within the limits of experimental error of the technique employed. However, it is apparent from the data that the precision and reproducibility of both the road and laboratory method are not as good as could be desired, and it is not likely that better correlation than has been found in these tests can be achieved until improvements in precision have been developed. Active work along these lines is in progress."



Correlation between road and laboratory ratings as established by the 1934 Detonation Road Tests at Uniontown, Pa.

The above illustration is Fig. 2 from the "Report of Cooperative Fuel Research Committee" presented by C. B. Veal at the 15th Annual Meeting of the American Petroleum Institute, Dallas, Tex., Nov. 14, 1934.

Safety Glass for Automotive Vehicles

A SPECIAL subdivision of the Passenger-Car Division has been cooperating closely for several months with a subcommittee of a Sectional Committee that was organized under the procedure of the American Standards Association to prepare a code of tests for safety glass, so-called. Due to the urgent need for such a code covering safety glass for use in motor-vehicles, a subcommittee of the Sectional Committee has drafted first a code for glass to be used in motor-vehicles. This code includes tests for three types of safety glass, namely the laminated, so-called heat-treated and the wired types. The code is practically completed and is now awaiting final approval by the general Sectional Committee on which the Society is represented by George L. McCain of the Chrysler Corp., and chairman of the Passenger-Car Division and also by H. C. Mougey, General Motors Research Corp., and W. H. Graves of the Packard Motor Car Co. and H. B. Haskins, Fisher Body Corp.

Screw Threads

ONE of the more important reports acted on by the Society at the last Annual Meeting was the revised American standard for screw threads and the revision of the S.A.E. Standard. The new report was submitted to the Society by the Sectional Committee on unification and standardization of screw threads last fall, the Society being co-sponsor with the American Society of Mechanical Engineers for this project under the American Standards Association. The report was sent to the Screw Threads Division which met in Detroit on Jan. 16 and recommended both approval of the report as American standard and as a basis of revision for the S.A.E. Standard (pp. 511-527 of the 1933 HANDBOOK).

This report supersedes the last preceding one that was issued in 1924. The principal changes embodied in the revised report effect the minor diameter in the nuts and include the addition of 8, 12 and 16 threads per inch series of screw threads covering class 2 and class 3 fit for the screw and the nut in the 8 and 12 pitch series and for the Class 3 fit for screws and nuts in the 16 pitch series. The revised S.A.E. Standard will include also new Class 2 and Class 3 fits for the

the Committees

screw and the nut in the extra fine series of pitches. All of the new tables in the S.A.E. Standard will be issued in the 1935 edition of the HANDBOOK. The present S.A.E. tables of pitch increments (pp. 526 and 527 of the 1933 HANDBOOK) will be superseded eventually by new tables for special pitches that are now being prepared by the Screw Threads Division.

Drill Jig Bushings

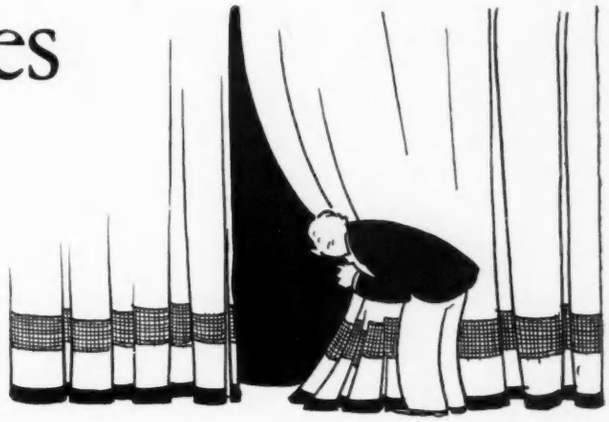
LATE last fall the Sectional Committee on Small Tools and Machine Tool Elements that was organized under the procedure of the A.S.A. with the Society, the American Society of Mechanical Engineers, and the National Machine Tool Builders Association as sponsors, prepared a recommended standard for drill jig bushings. This recommendation includes three types (a) the press fit wearing bushings (b) renewable wearing bushings and (c) linar bushings. The report was sent to the Production Division for their review and approval and then submitted to and approved by the Standards Committee and Society as a sponsor. The report will be published as an American Standard after it is finally approved by the A.S.A. but will not be published by the Society as an S.A.E. standard.

Knock-Rating Problems

A SUGGESTED program for the immediate future has been presented to the Cooperative Fuel Research Committee on Knock Rating Problems by T. A. Boyd. Under problems which appear to deserve attention in the further detonation work of the C.F.R. Committee, Mr. Boyd groups the following: the laboratory apparatus for procedure for knock testing, improving the precision of car knock ratings, instrumentation, reference fuels, rating aviation fuels for knock and sponsoring gasoline surveys of a national scope. Some of these problems were said to be an outgrowth of the recent Uniontown tests.

With respect to laboratory apparatus and procedure, Mr. Boyd points out that a more suitable fuel than benzene may be necessary for use in standardizing or checking the suitability of test conditions. A more definitely defined procedure for setting test conditions in respect to degree of intensity of knock may also be necessary, he adds.

There is need for a better degree of reproducibility between individual road ratings, he points out. Research is needed on the variables affecting the uniformity of car knock ratings. Some of the other points he makes are: the elimination of the personal factor from car knock ratings hinges upon the development of a dependable instrument for use in cars on the road. Ways and means for collecting and publishing information from periodical gasoline surveys of a national scope might be considered by the C.F.R. Committee. Research is now under way on the problem of providing a primary reference fuel suitable for making ratings above 100 octane number and that the work in investigation of detonation problems be continued at the National Bureau of Standards.



Front-Wheel Alignment

AT a meeting on Jan. 15, the Front-Wheel Alignment Research Subcommittee met, discussed and approved with minor revision the Code of Basic Definitions for Wheel Alignment including the elements caster, king pin inclination, camber and toe in. It was agreed that sketches picturing these elements should be shown directly following the definition of each element instead of on a separate consolidated sheet of sketches.

It was agreed that elements of steering linkage, of knuckle pin, bushing, and wheel bearing wear and of steering geometry should be continued as an appendix, and not in the body of the Code; also that definite dimensions for lost motion of the steering wheel, and for wear of knuckle pin, bushing and wheel bearings be fixed at an arbitrary maximum figure for further consideration.

It is proposed that the Code with Appendix as modified be sent, for very early approval, to each Committee member, to be resubmitted by him to his engineering and service organizations for further check with the objective of obtaining general approval of the Code and Appendix by the automotive industry. As soon as this general approval is secured, publication is proposed in the S.A.E. JOURNAL and in other technical publications.

Further committee work will be the compiling of 1935 passenger car and truck engineering specifications of wheel alignment data and the publications in such technical magazines as are suitable and willing to distribute these data for the benefit and use of wheel alignment service stations and states now requiring wheel alignment check up.

A preliminary discussion was held but no definite decision reached with reference to the possibility of urban organizations of mechanics handling wheel alignment and other mechanical service problems. Opinion was expressed that increased interest would result from such organizations specifically in the more efficient and uniform handling of mechanical problems, that such groups might become the arteries through which correct technical definitions and information might pass into actual practice, and that local S.A.E. Sections might be willing to help organize faster and supervise such a movement. Reference was made to a scheme for certifying the competence of mechanics, recently set-up and put into operation by the Institution of Automobile Engineers in England.

Ignition Research

DR. M. F. PETERS, who is in charge of the work of the ignition project at the National Bureau of Standards, presented some discussion at the aircraft engine session of the last Annual Meeting in Detroit. His work on the preignition quality of spark-plugs and its determination is being sponsored jointly by the Society and the Bureau of Aeronautics of the Navy Department. The discussion is expected to be prepared in the form of a paper for which release of material will be sought from the Navy Department.

The Ignition Research Subcommittee plans to assemble individually data on test methods and subjects for improvements and to pool available information on test methods for preignition at the next meeting which it is planned to hold in Washington shortly after Dr. Peters' paper is released. It was pointed out that the information to be presented at the next meeting of the Subcommittee will be concerned with all types of spark-plugs and not simply mica aviation plugs which the problem thus far has dealt with solely.

Research Committee Regulations

IN accordance with the resolution of the S.A.E. Council the Research Committee has prepared "Research Committee Regulations" with the aim of stating the objectives of S.A.E. Research defining its scope and organization, presenting a concept of its approved activities and establishing for them a recognized orderly procedure. All the matter in the new regulations has been harmonized with provisions of the S.A.E. Constitution and By-laws bearing on relative subjects.

Beginning with the general Research Committee all the research work of the Society will be handled by five types of organization divisions in the following order:

Research Executive Committee
Research Subcommittees
Research Divisions (subject to the approval of the Council subcommittees may be resolved further into such divisions as occasion may demand or the Research Committee may deem it expedient)
Special Committees

The Research Executive Committee was authorized at a meeting of the Council held during the last Summer Meeting of the Society. The new Research Committee Regulations will furnish the first complete statement of its function and read as follows:

(a) The Research Executive Committee shall advise the Research Committee and shall act as an alternate to it on such subjects as are delegated by the Research Committee, its actions being subject to review by the Research Committee.

(b) The Research Executive Committee shall function as an interim committee for the Research Committee on details of policy, execution and finance, all matters requiring Council action being first referred to the Research Committee.

(c) The Research Executive Committee, as occasion may arise, shall investigate and report to the Research Committee on the propriety and practicability of new research projects from the viewpoints of scope, program, necessity, timeliness, extent of demand, service to be rendered and adequacy and equity of financing arrangements.

(d) The Research Executive Committee, at least semi-annually, shall investigate and report to the Research Committee on the advisability of curtailing, suspending, or relinquishing to another organization any existing research project.

(e) The Research Executive Committee may, in the absence of any special committee designated for that purpose, act as a liaison group between the Research Committee and similar divisions of other Societies.

The Council of the Society has approved tentatively the formulation of the Research Committee regulations but approval of the final form has not yet been made.

Crankcase Oil Viscosity Classification

THE determination of the viscosities at zero of oils coming under the classifications 10-W and 20-W has been rather indefinite and after long consideration the Lubricants Division recommended the following:

"The viscosity at 0 deg. fahr. for oils No. 10-W, 20-W and S.A.E. No. 30 shall be determined on the standard Viscosity Temperature chart on the A.S.T.M. by extrapolating their respective curves of viscosities at 70 and 130 deg. fahr. This method shall be effective after Sept. 1, 1935." This recommendation will be included in the new HANDBOOK.

Another case that has been discussed at length by the division is the effective time of changes in the oil classifications or other petroleum product specifications adopted by the Society. These changes are likely to affect the marketing of petroleum products to a considerable degree and it was accordingly recommended that a definite policy as to effective dates be approved for publication. The following was accordingly reported by a subdivision and approved by the Lubricants Division and the Standards Committee: When changes in lubricant classifications are adopted by the Society their field application immediately following such adoption is optional, but it shall become fully effective 18 months following such adoption.

Propeller Shaft Ends and Hub Bores

AFTER a long and careful review of practice, the Motorboat and Marine Engine Division prepared and recommended a revised standard for propeller shaft ends and corresponding propeller hub bores for shafts up to and including 8 in. diameter for use in power boats. The larger sizes up to about 3 in. were included in the recommendation, for the larger sized boats and in view of the larger size shafts used with Diesel engines. This report was formulated with the cooperation of the Marine Propeller Manufacturers Association and adopted as their standard.

Dissolution of Headlight Research Subcommittee

AT the request of its chairman, Henry M. Crane, the dissolution of the Headlight Research Subcommittee has been authorized by the Research Committee. An expression of appreciation for the work of the Subcommittee was ordered sent to Mr. Crane by unanimous vote of the Research Committee.

The Research Committee approved also a letter of appreciation to the Automobile Manufacturers Association for their support of the headlight research work, the mechanics of which was handled in the Bureau of Standards laboratories in Washington.

Standard Lubrication Data Forms

MOTOR-VEHICLE lubrication data may now be compiled on S.A.E. Standard forms, following the completion of a project initiated in the Lubricants Division of the Standards Committee of the Society of Automotive Engineers in January, 1933. The standard forms consist of a set of four sheets to be cited as "Motor-Vehicle Lubrication Data Form—S.A.E. Standard," for which the final draft was approved at the last Annual Meeting of the Society in Detroit.

All manufacturers of motor-vehicles receive requests many times during the year for data on the lubrication requirements of their new models. These requests come from oil companies, lubrication-service data compilers, fleet operators, service stations, etc. Hitherto, any source which required data on a number of new models would receive a mass of unrelated facts, distinguished by its lack of uniformity. Usually it is necessary for each vehicle manufacturer to answer each inquiry separately, with consequent expenditure of time and money.

By obtaining a supply of the S.A.E. Standard form to cover his new models, the motor-vehicle manufacturer will be enabled to send each inquirer complete and standardized and accurate information at a minimum of cost, and with a minimum of trouble. The forms have been designed especially to be duplicated in quantity by any of the standard processes, such as blueprinting, photostating, or lithographing. One completion of the master form for a particular model of vehicle will take care of the matter until that model is superseded.

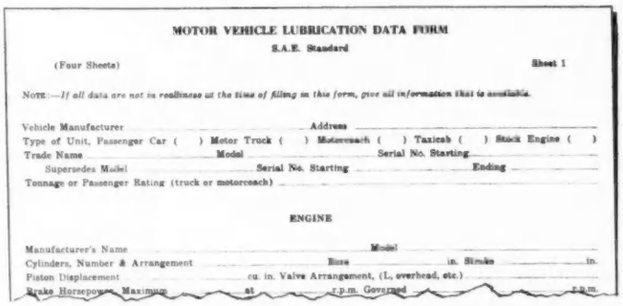
The new forms will be of particular interest to fleet operators and others who wish to have comparative information about the lubrication requirements of a number of types of vehicles. Undoubtedly the standard forms will find a ready acceptance by vehicle manufacturers, and that within a short time, requests for information about the lubrication requirements of their vehicles will be answered on copies made from the standard forms. Such a condition will, of course, permit ready filing and cross-indexing of information.

After careful consideration of the S.A.E. Council, the procedure to be followed in the distribution of the new lubricant forms by the Society has been established as similar to that for the S.A.E. Engine Testing Forms (gasoline and Diesel) which have been in wide use for many years; that is, the forms will be furnished at nominal cost to vehicle manufacturers, oil companies and others. The forms are available from stock at the S.A.E. office in New York, in sets of four sheets, at 25 cents a set to non-members, and 15 cents a set to members of the Society. Regular discount rates will be quoted on quantities.

The records of the S.A.E. Lubricants Division show that the suggestion which culminated in preparation of the forms originated with L. A. Danse, of the Cadillac Motor Car Co. The subdivision appointed to carry out the suggestion consisted of Dr. K. G. Mackenzie, chairman, Texas Co.; Sydney Bevin, then of the Tide Water Oil Co.; C. M. Larson, Sinclair Refining Co.; G. A. Round, Socony Vacuum Corp.; E. W. Upham, Chrysler Corp.; H. C. Mougey, General Motors Research Laboratories; and A. L. Clayden, Sun Oil Co.

Drafts prepared by this subdivision were revised several times during the two-year period since the project was

Parts are shown of each of the four sheets comprising a single set of Motor Vehicle Lubrication Data Forms, S.A.E. Standard.



MOTOR VEHICLE LUBRICATION DATA FORM
S.A.E. Standard
(Four Sheets) Sheet 1

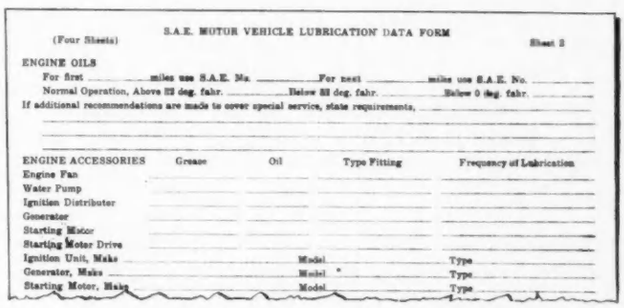
NOTE:—*If all data are not in readiness at the time of filing in this form, give all information that is available.*

Vehicle Manufacturer ____ Address ____
Type of Unit, Passenger Car ( ) Motor Truck ( ) Motorcoach ( ) Taxicab ( ) Stock Engine ( )
Trade Name ____ Model ____ Serial No. Starting ____
Supersedes Model ____ Serial No. Starting ____ Ending ____
Tonnage or Passenger Rating (truck or motorcoach) ____

ENGINE

Manufacturer's Name ____ Model ____
Cylinders, Number & Arrangement ____ Bore ____ in. Stroke ____ in.
Piston Displacement ____ cu. in. Valve Arrangement, (L, overhead, etc.) ____
Brake Horsepower, Maximum ____ at ____ r.p.m. Governed ____ r.p.m.

The first sheet provides space for listing the make, model and type of vehicle and for listing considerable data about the engine, including materials and make of components

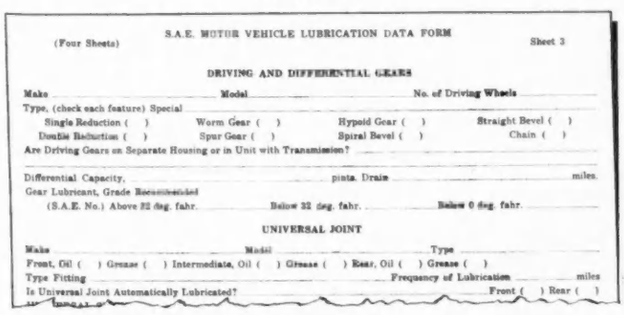


S.A.E. MOTOR VEHICLE LUBRICATION DATA FORM
(Four Sheets) Sheet 2

ENGINE OILS
For first ____ miles use S.A.E. No. ____ For next ____ miles use S.A.E. No. ____
Normal Operation, Above 32 deg. fahr. ____ Below 32 deg. fahr. ____ Below 0 deg. fahr. ____
If additional recommendations are made to cover special service, state requirements, ____

ENGINE ACCESSORIES	Grease	Oil	Type Fitting	Frequency of Lubrication
Engine Fan				
Water Pump				
Ignition Distributor				
Generator				
Starting Motor				
Starting Motor Drive				
Ignition Unit, Make			Model ____ Type ____	
Generator, Make			Model ____ Type ____	
Starting Motor, Make			Model ____ Type ____	

Sheet 2 is devoted to listing engine oil requirements, lubrication requirements of engine accessories, the clutch and transmission system.



S.A.E. MOTOR VEHICLE LUBRICATION DATA FORM
(Four Sheets) Sheet 3

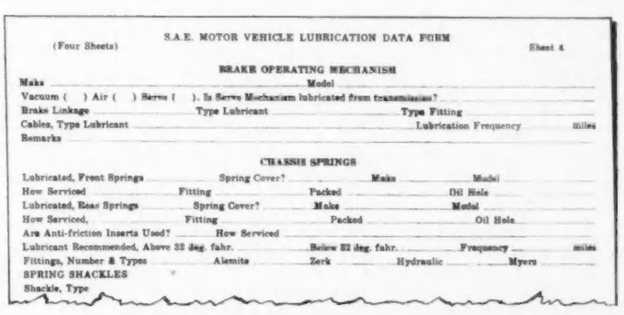
DRIVING AND DIFFERENTIAL GEARS

Make ____ Model ____ No. of Driving Wheels ____
Type, (check each feature) Special ____
Single Reduction ( ) Worm Gear ( ) Hypoid Gear ( ) Straight Bevel ( )
Double Reduction ( ) Spur Gear ( ) Spiral Bevel ( ) Chain ( )
Are Driving Gears on Separate Housing or in Unit with Transmission? ____
Differential Capacity, ____ pints. Drain ____ miles.
Gear Lubricant, Grade Recommended
(S.A.E. No.) Above 32 deg. fahr. ____ Below 32 deg. fahr. ____ Below 0 deg. fahr. ____

UNIVERSAL JOINT

Make ____ Model ____ Type ____
Front, Oil ( ) Grease ( ) Intermediate, Oil ( ) Grease ( ) Rear, Oil ( ) Grease ( )
Type Fitting ____ Frequency of Lubrication ____ miles
Is Universal Joint Automatically Lubricated? ____ Front ( ) Rear ( )

Sheet 3 covers driving and differential gears, universal joint, steering mechanism, wheel bearings and the central lubricating system.



S.A.E. MOTOR VEHICLE LUBRICATION DATA FORM
(Four Sheets) Sheet 4

BRAKE OPERATING MECHANISM

Make ____ Model ____
Vacuum ( ) Air ( ) Servo ( ). Is Servo Mechanism lubricated from transmission?
Brake Linkage ____ Type Lubricant ____ Type Fitting ____
Cables, Type Lubricant ____ Lubrication Frequency ____ miles
Remarks ____

CHASSIS SPRINGS

Lubricated, Front Springs ____ Spring Cover? ____ Make ____ Model ____
How Serviced ____ Fitting ____ Packed ____ Oil Hole ____
Lubricated, Rear Springs ____ Spring Cover? ____ Make ____ Model ____
How Serviced, ____ Fitting ____ Packed ____ Oil Hole ____
Are Anti-friction Inserts Used? ____ How Serviced ____
Lubricant Recommended, Above 32 deg. fahr. ____ Below 32 deg. fahr. ____ Frequency ____ miles
Fittings, Number & Types ____ Alemite ____ Zerk ____ Hydraulic ____ Myers ____
SPRING SHACKLES
Shackle, Type ____

Sheet 4, besides providing space for general lubrication instructions is designed for listing lubrication requirements of the brake operating mechanism, chassis springs, and shock absorbers.

initiated, and were approved finally by the Lubricants Division at a meeting on Jan. 16 of this year, and by the Standards Committee and the Council at meetings on Jan. 17.

Extreme-Pressure Lubricants Research

THE first sample of the test machine for extreme-pressure lubricants, built by the Highway Trailer Co. from designs prepared by T. C. Smith, engineer, motor vehicles and construction apparatus, American Telephone & Telegraph Co., was exhibited at the Annual Meeting of the Society in Detroit. The design for the machine was prepared by Mr. Smith, who is chairman of the Operators' Division of the Extreme-Pressure Lubricants Research Subcommittee, with the cooperation of his Division and the Executive Division.

A proposed procedure for conducting further tests was submitted to the E-P Subcommittee at the Annual Meeting and met with no objection. The present plan is to take the first machine, which was made available to the Committee through the courtesy of Dr. R. E. Wilkin, Standard Oil Co. (Indiana) and release it to Dr. Wilkin for preliminary runs and investigation. If the machine proves satisfactory, a limited number will be built and sold to those who wish to cooperate in the test program.

W. S. James, chairman of the Subcommittee, estimates that the machines would be available at a price of less than $500, exclusive of the driving motor. Money spent in the purchase of a machine, he indicated, should not be regarded as being spent for the purchase of a standard machine, but as a contribution to Committee work leading toward the evolution of a standard machine.

The question of whether the oils used for testing should be commercial grades or type-samples not necessarily available commercially was referred by motion to the Oils Division of the Subcommittee, Dr. Wilkin, chairman.

Oiliness of Crankcase Oils

THE investigation of the oiliness of crankcase oils is not an activity of the Research Committee except as a preliminary investigation of the problem, it was pointed out at a meeting of the Research Committee held during the last Annual Meeting of the Society in Detroit.

After a review by A. L. Beall of the informal conferences on the problem it was moved that the Research Committee organize a subcommittee to undertake the study of oils from the standpoint of their effect on bearings and in conjunction with this the effect of oils on engine life and wear or reduction of wear. The motion was carried and it was then stated that the procedure for undertaking this research will have to be worked out by the Research Executive Committee for presentation to the Research Committee as a whole.

T. B. Rendel suggested that the primary purpose of the Subcommittee would be to break down the problem and W. S. James suggested that the Subcommittee should be asked to give consideration to the determination of the ill-effects from the use of compounded or other pure mineral oils in engines.

Aviation Gasoline Detonation

AT the last meeting of the Cooperative Fuel Research Aviation Gasoline Detonation Subcommittee there were present, M. S. Kuhring, representing J. H. Parkin, assistant director of the division of physics and engineering of the National Research Council of Canada, and Squadron Leader Alan Ferrier, representing Capt. E. W. Stedman, chief aeronautical engineer, of the Department of National Defense of Canada. The organizations represented by these men have been invited to participate in the work of the C.F.R. Aviation Gasoline Detonation Subcommittee. The National Research Council of Canada is endeavoring to work out some means by which it can cooperate with the C.F.R.

Arthur Nutt, chairman of the Subcommittee, presented a report on progress made since the last summer meeting of the Society. In reply to a suggestion that some of the procedure data be omitted from the report and more detail included, Mr. Nutt said that the data are not complete and cannot be analyzed at the present time.

S.A.E. Tire and Rim Specifications

FOR a good many years tables of tire and rim sizes, inflation pressures, tire loads and other tire, rim and valve data had been published in the S.A.E. HANDBOOK. These have followed mainly similar specifications as published by the Tire and Rim Association but as each issue of the HANDBOOK was published many of these data had been obsoleted by changes approved by the rubber industry. Because of this situation the members of the division as well as the passenger car, motorcoach and motor-truck manufacturers were circularized as to the desirability of continuing the publication of these data in the HANDBOOK inasmuch as they are published and distributed by the Tire and Rim Association, and as to whether the vehicle manufacturers consider publication of these data in the S.A.E. HANDBOOK in selecting their tire equipment.

The result of this survey indicated a practically unanimous opinion, that the vehicle manufacturers are guided directly by contact with the tire companies in selecting their tire sizes, and that these data be discontinued in the HANDBOOK. Accordingly the Tire and Rim Division recommended cancellation of all the present S.A.E. specifications for tires, rims and valves, in the next edition of the HANDBOOK. The recommendation was approved by the Standards Committee and will affect those specifications printed on pp. 72-91, inclusive, of the 1933 HANDBOOK.

Outboard Motorboat Transoms

THE division also recommended a standard for the mounting of outboard motors, one type of mounting for ordinary installation and one for racing engines. This recommendation has been approved by the Standards Committee and will be included in the new issue of the HANDBOOK.

Tanks for Gasoline Tank Trucks

AS reported in previous issue of the S.A.E. JOURNAL, a subdivision of the Motorcoach and Motor-Truck Division, a subcommittee of the American Petroleum Institute and a committee representing the gasoline tank manufacturers formulated a series of standard diameters for the oval section of the tanks on gasoline tank trucks. The A.P.I. subcommittee also included in its recommendation a series of corresponding tank capacities, tank over-all length, and corresponding weight distribution on the front and rear axles in accordance with the S.A.E. Standard "CA" dimensions for the present conventional types of four or six wheel truck chasses. The Society however, has adopted only the oval diameters without relation to the other factors in the A.P.I. specification. They will be published in the new edition of the HANDBOOK.

S.A.E. Steels and Gray Cast Iron

TWO important reports have been submitted by the Iron and Steel Division, one being a complete revision and extension of the S.A.E. steel specifications, bringing them up-to-date. The division has worked for nearly a year on these revisions and the new specifications will be published in much more usable form than previously.

The new specification for automotive gray-iron castings has been adopted and will be included in the new HANDBOOK. These were developed by a special subdivision and with the cooperation of the subcommittee on automotive castings, of the American Society for Testing Materials. All of these specifications will be published complete in a separate bound pamphlet and will probably be ready for distribution about the first week in March.

Riding Comfort

ARRANGEMENTS have been made for the American Instrument Co. to manufacture and sell the Moss Wabblemeter developed through the Riding Comfort Subcommittee. Royalties from the sale of the instrument will be made available to further Riding Comfort Research as may be determined upon.

The immediate activity of the Subcommittee will be devoted to preparing a program for future research, the results of which promise to be immediately and beneficially applicable to the automotive industry as a whole. The immediate objective of the Subcommittee has been defined as follows:

"This committee believes that instrumentation and tests can answer the question, 'What is the best ride?' and provide means for evaluating the ride of the car. Measurement of horizontal and vertical acceleration is recommended."

Fuel and Lubrication Tube Fittings

AT a meeting of the Parts and Fittings Division in Detroit on Feb. 18, the present S.A.E. Standard (p. 185 of the 1933 HANDBOOK) was reviewed in view of complaints that had been received that in some instances trouble has been experienced with the smaller sizes of these fittings not gripping the tubing tightly. As the results of a survey that was made as to the most desirable revisions in these fittings dimensions a number of suggestions were considered by the division for incorporation in the standard when published. The division also considered the advisability of including recommended minimum tubing wall thicknesses for each size of fittings.

Crankcase Oil Stability

PURSUANT to a request from the Crankcase Oil Stability Research Subcommittee, its chairman, J. B. Fisher, is proceeding with the collection of information as to what men are actively engaged in projects relative to the subject and what information is now available. Available data on the subject will be collected and assembled for a report to be presented at the next meeting of the Subcommittee.

Meetings Calendar

S.A.E. Summer Meeting

The Greenbrier, White Sulphur Springs, W. Va., June 16-20, inclusive.

Baltimore—March 7

Engineers Club; dinner 6:30 P. M. J. F. Winchester, manager Automotive Department, Standard Oil Co. of New Jersey, will address the Section and show motion pictures of his trip in the Far East.

Buffalo—March 12

Statler Hotel; dinner 6:30 P. M. Rubber and Its Use in Transportation—Dr. A. W. Bull.

Canadian—March 20

Royal York Hotel, Toronto; dinner 7:00 P. M.

Chicago—March 5

Hamilton Club; dinner 6:45 P. M. Economics of Automotive Transportation—Pierre Schon, transportation engineer, General Motors Truck Co.

Cleveland—March 11

Cleveland Club; dinner 6:30 P. M. Modern Methods in Automotive Manufacturing—Joseph Geschelin, engineering editor, *Automotive Industries*.

Dayton—March 14

Engineers Club; meeting 8:00 P. M. Humanized Automotive Engineering—R. N. Janeway, Research Division, Chrysler Corp.

Detroit—March 18

Book-Cadillac Hotel; dinner 6:30 P. M. Passenger-Car Session.

Indiana—March 11

The Athenaeum; dinner 6:30 P. M. Use of Aluminum in Automotive Aircraft and Diesel Engines—G. D. Welte, engineer, Aluminum Co. of America.

Kansas City—March 18

Metropolitan—March 11

Roger Smith, 40 E. 41st St., New York; dinner 6:30 P. M. Basic Principles of Fleet Operation—T. L. Preble, supervisor motor transportation, Tide Water Oil Co. Highway Investigation of Carbon Monoxide in Moving Vehicles—F. M. Van Deventer, Cities Service Co.

Milwaukee—March 6

Milwaukee Athletic Club; dinner 6:30 P. M. Problems in the Development of a High-Speed Engine—Stanwood W. Sparrow, engineer, Research Department, Studebaker Corp.

New England—March 13

Walker Memorial, Massachusetts Institute of Technology, Cambridge; dinner 6:30 P. M.

Northern California—March 12

Engineers Club, San Francisco; dinner 6:30 P. M. Subject—Trucks and Trailers.

Northwest—March 8

New Washington Hotel, Seattle; dinner 6:30 P. M.

Oregon—March 8

Lloyd's Club House, Portland; dinner 6:30 P. M. Lubricating Oils—by a representative of the Union Oil Co. Diesel Engine Fuels—by a representative of the Standard Oil Co.

Philadelphia—March 13

Philadelphia Auto Trades Association; dinner 6:30 P. M. Symposium on Power Brakes.

Pittsburgh—March 5

Pittsburgh Athletic Association; dinner 6:30 P. M.

Southern California—March 9

Jonathan Club, Los Angeles; dinner 7:00 P. M. Annual Dinner Dance and Entertainment.

Washington—March 4

University Club, Washington, D. C.; dinner 6:30 P. M. Mechanical Applications of Electro-Deposited Coatings—Dr. Richard M. Wick, assistant chemist, National Bureau of Standards. Safety Glass for Glazing Automobiles—A. N. Finn, chief of Glass Section, National Bureau of Standards.

—April 1

The University Club, Washington, D. C.; Speaker—John Geisse, chief, Development Section, Bureau of Air Commerce.

News of the Society

American and Foreign Motor Shows Described

● Indiana

When we want to make an arrow go unerringly straight forward we weight it with an iron head. It follows the heavy end without turning to either side. Unfortunately we do not always want our cars to go straight forward. The roads turn, kink, twist, and curve. Will the tendency toward weighting down the front ends make arrows of our cars and cause them to seek the straight path when we would like very much to follow the curving road and safety?

This was one of the rhetorical questions with which Lee Oldfield spiced his review of new models and new tendencies at the Feb. 14 meeting of the Indiana Section. Heavy front ends, adequacy of brakes, and tire wear under independent springing were all discussed following the paper.

Another phase of the discussion brought out the opinion that the new 1934 and 1935 types with tremendously increased power, unsuspected silence and lack of vibration may have helped raise the accident rate of 1934. Even experienced drivers who had driven old models until easier times gave them a chance to go modern last year, often got into difficulty. Lulled by the smooth operation, unaccustomed to new extremes of acceleration and quiet, they did not watch the speedometer and went into curves at far too high a speed. One car rolled on a curve the driver and passengers thought was about 35 m.p.h. The same car was later driven around that curve at 65 without the slightest sign of sway or trouble. "But," said Mr. Oldfield, "that is one of the difficulties of the situation. No one really seems to know the answer." Experimental driving on some cars developed that fact when trouble comes in taking curves too fast, or front skids, it comes like a flash with no slightest indication of unbalance until it is too late. Some cars were driven faster and faster around certain curves. Trial after trial was made at higher speeds each time, with no slightest indication of trouble until the critical speed was reached.

Chairman A. W. Herrington's "Review of the Paris and London Shows" emphasized the enormous display that in Paris makes even our New York Show look Austinish, and smothering crowds of spectators that made it impossible to see the displays unless one crowded under the canvas before the doors were opened for the shoppers. Another striking Paris feature was the vintage models of 1904 and earlier years that offered practically as many cars for the spectator to marvel at as the entire New York display. Extreme refinements such as the Lancia, smoother, beautified to the last word with even the engine accessories concealed in the smooth block that could be wiped off with a handkerchief—perhaps the most beautiful car ever produced—and not far off less swanky types with "tin work so rough that even a junior American inspector would reject it." They simply have not the facilities for sheet-metal work. Maybe that's the reason why one British patrioteer who shouts to high Heaven, "Make and Sell British," imports his sheet metal parts and fenders from Detroit, while Ford in Britain employs even British raw materials and doesn't import a nickel's worth for his British product, Mr. Herrington offered.

They go all the way on independent springing. Only their knees are absolutely hidden. They take them for granted, and have probably fitted them so well that even the service man doesn't need to inspect or get at them, were some more of his conclusions.

Power, on the other hand, must be heard in sport models in Britain or they simply aren't attractive. External exhaust bodies of extreme discomfort, steering as hard as an old time truck seem to be swank. In the racing sport jobs on Brooklands, engines of 61 in. in some cases were equipped with blowers twice the size of the engine block. Incidentally, Mr. Herrington said, they did their 500 at a pace within a few hundredths of a mile of the last American 500-mile record and did it in a rain that poured most of the time. Even some of the little jobs can do 128 m.p.h. at Brooklands. They also have lots of fun running five or six classes or more at one time, handicapped. Maybe lifting the anti-blower ban might be good things for the customers some coming May at Indianapolis, he indicated.

Brown and Gurney Discuss Railcars

● Metropolitan

That the railways of this country will have to turn to automotive equipment for most passenger service was the opinion advanced at a well attended meeting of the Metropolitan Section of the Society of Automotive Engineers, held in New York, Feb. 11. Lowell H. Brown and Erving R. Gurney, joint authors of a paper entitled "Technical and Economic Phases of Railroad Automotive Development", were the principal speakers; there was a lively discussion in which both automotive and railway engineers joined.

In the paper the authors first outlined the economic situation which they contend makes necessary a change in passenger-carrying facilities. They next showed the various types of automotive railway equipment now in use here and abroad and finally described a modified type which they consider better suited for railway use.

Those who took part in the discussion included S. N. Mills, Interstate Commerce Commission; P. H. Hatch, New York, New Haven and Hartford Railroad; W. R. Hedeman, Baltimore & Ohio Railroad; J. K. McNeillie, Delaware & Hudson Railroad; C. B. Peck, *Railway Age*, Merrill C. Horine, Mack Truck Co.; E. S. Hall, consulting engineer; Joseph A. Anglada, Anglada Motor Corp.; O. F. Allen, consulting engineer; and Herbert Chase, who acted as Chairman of the meeting.

Although the railway men expressed some scepticism regarding automotive equipment, they indicated that it is fitted for and needed in some classes of service. Some of the automotive engineers pointed to traffic regained by railroads who have provided modern equipment and given more frequent and faster service. The reliability of the modern automotive engine has fitted it for railway applications. Some question was raised over the feasibility of mechanical transmissions in cars of over 200 hp., but the high cost and weight of electric transmissions was considered a serious drawback to that type. The success of some forms of automotive railcars here and in Europe was mentioned as was also certain difficulties in servicing encountered there.

In closing, Mr. Brown stated that taxpayers will not long consent to making up the losses in revenue on passenger service which the railroads now suffer and will wait on changes designed to overcome these losses or will take over the railroads for Federal operation, which has always proved expensive. Only by cooperation on automotive railway developments by the railroads can a satisfactory solution be found, in Mr. Brown's view.

Burwell Presents New Oil Data

● Buffalo

Dr. Arthur W. Burwell presented a paper on "New Ideas in Lubrication" at the Feb. 12 meeting of the Buffalo Section held at the Hotel Statler. Discussion of the paper was contributed by C. W. Georgi and Laurence P. Saunders. The meeting was attended by 70 members and guests with 28 at the dinner preceding.

Eighty Listen To Chase's "Pokes"

● Philadelphia

A group of about 80 people attending the February meeting of Philadelphia Section was treated to one of the most interesting presentations of the season by Herbert Chase who developed the second edition of his oft-discussed "Pertinent Pokes at Contented Engineers." Joseph Geschelin, engineering editor, *Automotive Industries*, presided.

What Mr. Chase did particularly well was to take from his original paper, a specific group of criticisms and pit them against the advances that may have been made since then, as represented in the 1935 passenger cars. According to Mr. Chase, if his criteria are sound, little progress can be recorded.

In his opinion, clear vision still is lacking in most cars. Headroom is no better and derby hats still are in danger. The tendency to lower center of gravity appears to be less of a safety factor than is realized, if it is agreed that a lower center of gravity makes for better side skidding. Engines are too large and too heavy, and the eight-in-line may be on its way out.

Confirming what others have said recently, the speaker stated that the present development of streamlining is simply a style element with but little of the fundamental theory satisfied. Lower frames and smaller road clearances have further complicated the servicing of cars and have made accessibility more difficult.

On the credit side of the ledger, Mr. Chase noted the trend to more comfort for the passengers and commented on the apparent passing of independent springing, proving that conventional suspensions can be used to produce a better ride. Electrical systems have improved greatly, what with ventilated generators and provision for voltage regulation.

Mr. Chase likes the Stout Scarab better than anything that has appeared on the horizon and predicts that rear engined cars with more passenger space are just around the corner.

The talk was profusely illustrated by the use of lantern slides and wound up with an extremely humorous volley directed at the extravagant claims made by the advertising engineers.

The meeting wound up with a very lively discussion of many of the controversial points brought up by Mr. Chase, starting off with a statement by B. B. Bachman of Autocar that he disagreed with practically every criticism voiced by the speaker. Among those participating in the discussion were: E. B. Neil, J. P. Stewart of Socony-Vacuum, J. D. Rohrer of U. S. Asbestos, J. C. Geniesse of Atlantic Refining, F. L. Creager of R.C.A. and C. O. Guernsey.

Truscott Speaks At "N.A.C.A. Night"

● Washington

Starr Truscott, aeronautical engineer, National Advisory Committee for Aeronautics, in charge of the N.A.C.A. Tank at Langley Field, Virginia, was guest speaker at the "N.A.C.A." meeting of the Washington Section held on Feb. 4, following a dinner at the University Club.

Mr. Truscott outlined the history and development of seaplanes with regard to the characteristics and design of floats and flying-boat hulls. Some of the early attempts to float airplanes on rectangular floats replacing the wheels were pictured and described. Out of the numerous disappointments experienced with the early models came the development of various hull sections, such as vee, vee-curves and so on, these designs being much improved by the addition of the "step" in the bottom. Later model hulls incorporated several steps. These improvements caused turbulence, admitting air beneath the hull, and so reducing its drag. Mr. Truscott pointed out that failure of a flying boat to take off, even though sufficiently powerful engines are used, may be due entirely to incorrect hull design having high drag.

He showed a series of slides depicting the development of the seaplane and flying boat, among those shown being War-time British and American boats, Rohrbach's boats, the Dornier DO-X, some of the French boats, France's newest giant seaplane to be used on trans-atlantic flights, and the latest models of Sikorsky.

Horine Presents Maintenance Question

● Pittsburgh

Merrill C. Horine, sales promotion manager, International Motor Co., asked and answered the question "Does Maintenance Pay?" at the Feb. 5 meeting of the Pittsburgh Section. The outstanding feature of Mr. Horine's talk, according to the report, was his method of representing the difference between a new vehicle and one which has been operated several thousand miles.

Mr. Horine presented about 5 lb. of finely ground metal—iron, brass, babbitt—representing the metal worn away from vital parts thus rendering the vehicle unfit for further service. The remainder of the metal in the vehicle he said was still there and just as serviceable as ever. Proper maintenance he indicated causes this loss of metal from vital parts to progress more slowly, keeping the vehicle serviceable for a long time.

The discussion brought out points not touched in the paper. It was said, for instance, that the rate of obsolescence from now on is not likely to be so fast as it has been in the past, because the near future does not promise any such relatively fundamental changes as the change from four to six-cylinder truck chassis and the advent of pneumatic tires for heavy vehicles.

Mr. Horine predicted that even the Diesel engine will not replace rapidly the gasoline engine. Diesels can be built to fit the present chassis so that change over can be made if desirable without scrapping the whole vehicle.

Lubrication, Safety Joined on a Program

● Chicago

Three speakers on lubrication subjects were on the program of the Jan. 29 meeting of the Chicago Section, attended by 153 members and guests. J. Howard Pile, editor, Chek-Chart Corp., presided at the meeting and spoke on "Major New Car Changes and the Outlook for 1935." During the dinner which preceded the meeting, B. L. Majewski, president, Deep Rock Oil Corp., told of "Experiences with the Code." The third speaker was William J. Gerwe, manager, automotive division, Socony-Vacuum Oil Co. His subject was "Lubrication as it Affects Safety in Automobiles."

The necessity of educating the public and those who sell lubricants in the relation of lubrication to safety was stressed by Mr. Gerwe in a talk which brought out considerable discussion at its conclusion.

L. V. Newton, for instance, cited the high standing of commercial fleets from the standpoint of satisfactory lubrication practice, and urged the desirability of more simplification in lubrication requirements.

Earl C. Rieger, International Harvester Corp.; Fred L. Faulkner, Armour & Co.; Stewart Grant, Pure Oil Co.; and R. T. Hendrickson, Hendrickson Motor Truck Co., were among those contributing to the discussion.

Mr. Faulkner made the suggestion that a committee be formed from the membership of the Chicago Section to cooperate with other Chicago organizations in furthering a safety program. As a motion, the suggestion was adopted.

Diesels and Roads On Divided Program

● Oregon

The United States is now foremost in Diesel engine design and manufacture and is far ahead of Europe on this subject according to Prof. Peter Muntz, Adcox Trade School, the speaker at the Jan. 11 meeting of the Oregon Section. J. Verne Savage, treasurer of the Section, presided at the meeting.

The second speaker of the evening, Robert W. Mann, discussed "Speedy Trail and Road Building" and followed with three reels of motion pictures.

The meeting was attended by 31 members and guests with 27 at the dinner preceding.

The first picture to be taken in many years of the full personnel of the National Advisory Committee for Aeronautics is shown above. From left to right in the picture the members are: John F. Victory, secretary; Dr. Charles G. Abbot, secretary, Smithsonian Institution; Hon. Harry F. Guggenheim; Willis R. Gregg, chief, U. S. Weather Bureau; Dr. L. J. Briggs, director, National Bureau of Standards; Dr. Joseph S. Ames, chairman, retiring president, Johns Hopkins University; Dr. George W. Lewis, director of Aeronautical Research; Comm. R. D. Weyerbacher, U. S. N.; Lt. Col. Henry C. Pratt, U. S. A., chief, Materiel Division, Air Corps; Rear Admiral Ernest J. King, U. S. N., chief, Bureau of Aeronautics; Maj. Gen. Benjamin D. Foulois, U. S. A., chief, Air Corps; Dr. Orville Wright; and Hon. William P. MacCracken, Jr. Messrs. Wright, Foulois, Lewis, and MacCracken are members of the Society of Automotive Engineers.

Papers Available in Mimeographed Form

UNTIL current supplies are exhausted, copies of the papers listed are available in mimeographed form at a cost of 25 cents per copy to members; and at 50 cents per copy to non-members. Orders should specify the name of the author as well as the title of the paper desired.

Orders must be accompanied by remittance and should be addressed to Sessions Secretary, Society of Automotive Engineers, 29 West 39th St., New York, N. Y.

Alden, C. R.
Design and Development of Injection Apparatus for High Speed Diesels

Altman, Peter
Sales and Technical Problems of Private Commercial Airplanes

Ballard, J. H., Nixon, S., and Moore, N. A.
Piston Rings: Factors Contributing To Their Normal and Abnormal Wear

Barish, Thomas
Bearings for Controllable Propellers

Bleicher, C. E.
Relative Merits of Precision Manufacturing and Correct Plant Layout to Accomplish Cost, Quality and Uniformity of Parts Production

Bockius, C., and Hunt, J. Harold
Brake Drum and Lining Development

Britton, Roy F.
Taxation and Regulation as Applied to Highway Transportation

Brown, Lowell H., and Herbert Chase
Streamlining—Up-to-date Facts and Developments

Clinton, G. E.
Problems of Industry in Using the Highways

Croll, P. R., and DuBey, L. E.
How to Finish a Truck

Debbink, H. S.
Some Factors Influencing Gasoline and Oil Consumption

De Forest, A. V.
Surface Integrity and Dynamic Strength

Dennison, E. S.
A Rational Basis for Comparing Diesel Performances

DeSmet, E. C.
The Practical Side of Planography

Dick, Burns
Hydraulic Brake Actuation

Dunbar, H. W.
1934 Developments in Cam and Cylindrical Grinding

Elliott, Frank
History of Racing and Fuel Development

Fassler, P. W.
Modern Resistance Welding in the Automobile Industry

Faulkner, F. L.
Motor Vehicle Design from the Operation and Maintenance Standpoint Part Two

Ferrier, Alan
Cold Weather Operation of Aircraft Engines

Foster, A. L.
Prospects for Future Diesel Fuels, and Their Available Supply

Geisse, J. H.
Air Transportation Equipment for the Private Owner

Geniesse, J. C.
Fuel and Oil Economy for the Operator

Gregory, A. T.
Cylinder Events Studied in the Logarithmic Diagram

Gurney, E. R., and Brown, L. H.
Technical and Economic Phases of Railroad Automotive Development

Hardy, F. I.
Economic Application of Rates for Movement of Freight by Motor Trucks

Havill, C. H.
Theory and Characteristics of Eclipse Automatic Variable Pitch Propeller

Heron, S. D.
Aircraft and Aircraft Engine Performance as Influenced by Engine Oil

Kindelberger, J. H., and Atwood, J. L.
The Designer's and Manufacturer's Viewpoint on the Requirements for Aircraft Intended for Airline Operation

Larson, C. M.
The Realm of Extreme Pressure Lubricants

Littlewood, William
Operating Requirements for Transport Airplanes

Lott, E. P.
Air Transport Operations

Markham, H. B.
Trend in Taxation and Regulation of Highway Transportation

Nohavec, F. R.
Air Conditioning as Applied to Internal Combustion Engines

Nutt, Arthur
Report of C.F.R. Aviation Gasoline Detonation Subcommittee

Padgett, J. E.
Machinery and Equipment Policies in View of the Present Business Situation

Preble, T. L.
How to Buy a Truck

Probst, K. K.
Transverse Leaf, Independent Springing

Rassweiler, G. M., and Withrow, Lloyd
Engine Flame Temperatures Vary with Knock and with Position in the Combustion Chamber

Reid, E. G.
Farewell to the Horseless Carriage

Rendel, T. B.
Progress Report of Volunteer Group for C. I. Fuel Research

Saurer, Curt
Engineering Uses of Rubber

Schlesman, C. H.
The Lubrication Requirements of Automotive Worm Gearing

Sloan, W. J.
Planning and Administering Highway Systems for Greatest Usefulness

Smith, G. W., Jr.
A Technical Education

Spring, F. S.
Are We Giving the Average Private Operator the Airplane Most Suitable to His Needs?

Taylor, C. P.
Fitting the Highway to Traffic

Taylor, E. S.
Design Limitations of Aircraft Engines

Tinkham, G. L.
Truck Refrigeration with Propane

Tirrell, E. L.
Weight Distribution on Front and Rear Axles of Motor Truck

Veal, C. B.
Mind or Micrometer

Veal, C. B.
Report of Cooperative Fuel Research Committee 1934 Detonation Road Tests

Wheeler, P. R.
Human Engineering

Winkler, A. H.
Service Problems and Trends in Motor Vehicle Maintenance

Wise, W. F.
Single Point Boring of Cylinders and Diamond Turning of Pistons

Wolf, A. M.
Lightness in Truck Design

Wright, T. P.
Controllable Pitch Propellers—Design Considerations

K.T. Keller

SAYS:

"It seems to me that every automotive engineer owes it to himself to join the S.A.E. if he can possibly do so."

Mr. Keller is president of the Dodge Bros. Corp., Detroit. One of the best known executives in the automotive industry, his opinion of the S.A.E. is founded on many years of observation of its men and policies in action.

●

THE SOCIETY OF AUTOMOTIVE ENGINEERS, INC.

W. C. KEYS, *Chairman*, Membership Committee

What Members Are Doing

John W. Brussel, formerly vice-president of the Wolverine Machinery & Supply Co., Detroit, became manager of the Federal Mogul Corp., Detroit, on Feb. 11. Mr. Brussel recently became a member of the Production Activity Committee of the Society.

George D. Evans has been appointed a member of the engineering staff of the Hammond Aircraft Corp., Ypsilanti, Mich. He was formerly engineer with the Curtiss Wright Airplane Co., Robertson, Mo.

Leonard V. Newton has been appointed a colonel on the staff of Governor Ruby Lafoon, of Kentucky.

Col. Frederick W. Miller, formerly Ontario sales manager for Collins & Aikman of Canada, Ltd., has been appointed assistant general manager of the company.

Hugh L. Hemmingway, formerly C.F.R.-engine operator for the Ashland Refining Co., Ashland, Ky., has joined the Kendall Refining Co., Bradford, Pa., as lubrication engineer.

Athel F. Denham, for the past 8 years Detroit editor for the Chilton Co., and its group of automotive publications, has announced the establishment of an automotive technical advisory service on advertising and

Athel F. Denham

publicity, with headquarters at 1235 Lafayette Building, Detroit. In addition to his consulting work, Mr. Denham will be editorial representative in Detroit for *MoToR* magazine.

J. Bennett Hill, formerly chief chemist of the Atlantic Refining Co., Philadelphia, has joined the Sun Oil Co. at Marcus Hook, Pa.

Howard Ketcham, director of the Duco Color Advisory Service and editor of the *Automobile Color Index,* has opened his own office at 545 Fifth Ave., New York, where he will practice as an advisor on color problems in industry. He will continue his connection with the DuPont interests as a color consultant, specializing in promoting the correct relationship between product and market.

Charles Sharp Crawford

Charles S. Crawford, chief engineer of the Opel Works, General Motors subsidiary in Germany, died January 28 in Indianapolis while

C. S. Crawford

on leave of absence. Mr. Crawford had served as a Councilor of the Society and was twice chairman of the Indiana Section. He was a brother of James M. Crawford, chief engineer, Chevrolet Motor Co.

Mr. Crawford began his career as an automotive engineer with the old Lozier Motor Car Co., where he was experimental draftsman. After a short period outside the industry he joined the Cole Motor Car Co. in 1910 as mechanical engineer, and was successively purchasing agent for the Empire Motor Car Co. and engineer and factory manager for the Westcott Motor Car Co. He rejoined Cole in 1911 as special assistant to the president of the company. In 1916 he joined the Premier Motor Car Co. as assistant general manager, later becoming vice-president before his resignation in 1921 to open a consulting engineering office in Indianapolis. May of the following year took him to the Stutz Motor Car Co. as chief engineer, a position he held until his resignation in 1928 to join the General Motors Corp.

Illness caused him to submit his resignation to the Corporation last July; but instead of its being accepted a year's leave of absence was substituted.

At the Feb. 14 meeting of the Indiana Section, Chairman A. W. S. Herrington voiced the regret of the Section at the untimely death of Mr. Crawford, pointing out that he was one of the pioneers of S.A.E. work in Indianapolis and the Indiana Section.

At the above meeting, on a motion from the floor by Charles Merz seconded by Lee Oldfield, the secretary of the Section was ordered to prepare a memorial resolution expressing the esteem of the Section for him and its keen regret at his death.

Hugo Junkers

Prof. Dr. Hugo Junkers, world famous designer and constructor of all-metal airplanes and engines, died in Munich, Feb. 3, at the age of 76. Dr. Junkers severed his relations with the Junkers-Werke of Dessau, Germany, in October of 1933 when the company was reorganized with the aid of a government subsidy. The company had been founded by him 40 years before.

He was elected a member of the Society of Automotive Engineers in 1924, his sponsors being Prof. Alexander Klemin, the late Coker F. Clarkson, Dr. George W. Lewis, William Knight and Georg H. Madelung. At the time of applying for membership he listed his specialties as, motors, calorimeters, heating apparatus and airplanes. To all of these subjects Prof. Junkers contributed the benefit of sound engineering effort.

His original patent for an all-metal airplane was issued in 1910. The world war prevented the international diffusion of the art in which he pioneered and it was not until after the war that he was enabled to extend his efforts in a commercial way. Germany was forbidden to build military aircraft so Prof. Junkers formed a working agreement with the airlines of foreign countries which became the nucleus for the vast German network now called Lufthansa.

Junkers engines have powered many famous aircraft both in the heavier-than-air and lighter-than-air field. Their inventor was a frequent visitor to the United States.

Applications Received

(Continued from page 29)

Miyata, Junichi, manager, Okura & Co., New York City.

Morris, Donald L., owner, Don L. Morris Co., Palo Alto, Cal.

Munson, Amos Keller, engineer of construction, United Traction Co., Albany, N. Y.

Novack, Harry, motor truck maintenance and service, Humboldt Lumber Co., Inc., Brooklyn, N. Y.

Orlando, Alexander, director, "Ala Littoria S.A.". Venice, Lido, Italy.

Ovens, William George, test engineer, Wright Aeronautical Corp., Paterson, N. J.

Petrovsky, Evgeni Ivanovich, representative in U.S.A., United Aircraft Industries of the U.S.S.R., New York City.

Roach, E. D., sales manager, equipment division, central district, Edison-Splitdorf Corp., West Orange, N. J.

Robinson, Andrew, owner, W. Robinson & Son, Lismore, N.S.W., Australia.

Risteen, Horace William, assistant professor of mechanical engineering, Michigan College of Mining and Technology, Houghton, Mich.

Rolph, S. F., general manager, The Yale & Towne Mfg. Co., Detroit.

St. John, R. C., draftsman, N.R.W.R. Office, State Highway Department, Bismarck, N. D.

Smith, Donald A., engineering advisor, American Tire Guard Co., Detroit.

Solache, Alberto Antolin, chief engineer, S.A.T.I.A., Moreno 1748, Buenos Aires, Argentina.

Sprague, Gale Alton, special assignment engineer, Olds Motor Works, Lansing, Mich.

Stapleton, H. N., instructor, The Pennsylvania State College, Department of Agricultural Engineering, State College, Pa.

Stein, George F., student, Boeing School of Aeronautics, Oakland Airport, Cal.

Stitz, Ervin O., draftsman, Ross Gear & Tool Co., Lafayette, Ind.

Teulings, R. Lawrence, tire service engineer, Public Service Coordinated Transport, Newark, N. J.

Treuting, Herbert R., chemical engineer, American Machine & Foundry Co., Brooklyn, N. Y.

Vande Water, Murray Earl, president, general manager, Refining Industries, Inc., Portland, Oregon.

Whetstone, Lee M., supervisor of motor transportation, The Atlantic Refining Co., Philadelphia.

SWIFTLY...

THE STEEL PICTURE CHANGES

NEW ANALYSES . . . advances in grain refinement . . . improvements in processing—all follow so rapidly that steels considered perfectly satisfactory for certain applications only a year ago are too costly today.

● For example, Republic's Improved Series of S. A. E. 3100 Steels are made to new standards of metallurgical control. They are finer grained and far superior in many respects to the former 3100 steels. They machine more readily and are suitable for many applications for which higher priced alloy compositions are now being used.

● When a Republic man asks, "Can our Metallurgists help you?" he is offering you the collective knowledge and experience of a metallurgical staff that is abreast of every new development. Perhaps these Republic Metallurgists can help you reduce costs and improve your product.

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EXTREME PRESSURE ("E.P.")
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MODERN
AUTOMOBILES
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REQUIRE
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LUBRICANTS

★ ★ ★ ★

"STURACO" EP
OILS AND
GREASES
ARE AS
MODERN AS
TOMORROW

★ ★ ★ ★

YET
HAVE BEEN
TRIED
AND
TESTED BY
FIVE
YEARS OF
ACTUAL USE
IN
THOUSANDS
OF
VEHICLES

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Notes and Reviews

THESE items, which are prepared by the Research Department, give brief descriptions of technical books and articles on automotive subjects. As a rule no attempt is made to give an exhaustive review, the purpose being to indicate what of special interest to the automotive industry has been published.

The letters and numbers in brackets following the titles classify the articles into the following divisions and subdivisions: *Divisions*—A, Aircraft; B, Body; C, Chassis Parts; D, Education; E, Engines; F, Highways; G. Material; H, Miscellaneous; I, Motorboat; J, Motorcoach; K, Motor-Truck; L, Passenger Car; M, Tractor. *Subdivisions*—1, Design and Research; 2, Maintenance and Service; 3, Miscellaneous; 4, Operation; 5, Production; 6, Sales.

AIRCRAFT

Seaplane Design

By William Nelson. Published by *McGraw-Hill Book Co., Inc., New York and London*, 1934; 274 pp., illustrated. [A-1]

The author sets forth his belief that the seaplane is awaiting a favorable opportunity to extend its importance in the field of transportation and offers this textbook on seaplane design with the idea that this type of craft is destined to be built in much larger sizes than at present.

It is pointed out that the theory of seaplane design involves airplane design and marine design on both of which many good books are available. This volume, therefore, treats only the seaplane problems peculiar to that particular craft, and the original theories concerning them.

Aerodynamic Theory Vol. II

By William Frederick Durand. Published by *Julius Springer*, Berlin, 1935; 367 pp., illustrated. [A-1]

This book is the second in the series covering a general review of progress in this field, prepared under a grant of the Guggenheim Fund for the Promotion of Aeronautics. Volume I was reviewed in these columns of the October, 1934, Journal.

Volume II treats the subject of the aerodynamics of perfect fluids, the contributors are Th. von Kármán, Director of the Guggenheim Aeronautics Laboratory, California Institute of Technology, and formerly Director of the Aerodynamic Institute, Aachen, Germany; and J. M. Burgers, Professor of Aero- and Hydrodynamics at the Technische Hoogeschool at Delft, Holland.

Aerodynamic Effects of a Split Flap on the Spinning Characteristics of a Monoplane Model

By M. J. Bamber. N.A.C.A. Technical Note No. 515, December, 1934; 8 pp., 5 figs. [A-1]

The Experimental Investigation on the Effects of Cut-Out on the Wing Characteristics

By Tetusi Okamoto. Report No. 113 of the Aeronautical Research Institute, Tokyo Imperial University, October, 1934; 137 pp., with tables and charts. [A-1]

Cavitation des Hélices Marines et Ondation des Hélices Aériennes et des Sustentateurs Mobiles des Machines Volantes

By Wladimir Margoulis. Published in *L'Aéronautique*, January, 1935, Aérotechnique Section, p. 1. [A-1]

The author, at present advisor to the Japanese admiralty on high-speed wind tunnels, discusses the problem of cavitation in marine propellers. He explains how a similar phenomenon, which he terms the formation of shock waves, acts to the detriment of high-speed propeller efficiency. For the study of this and other problems connected with propellers operating at exceedingly high speeds he proposes special wind tunnels, which he describes.

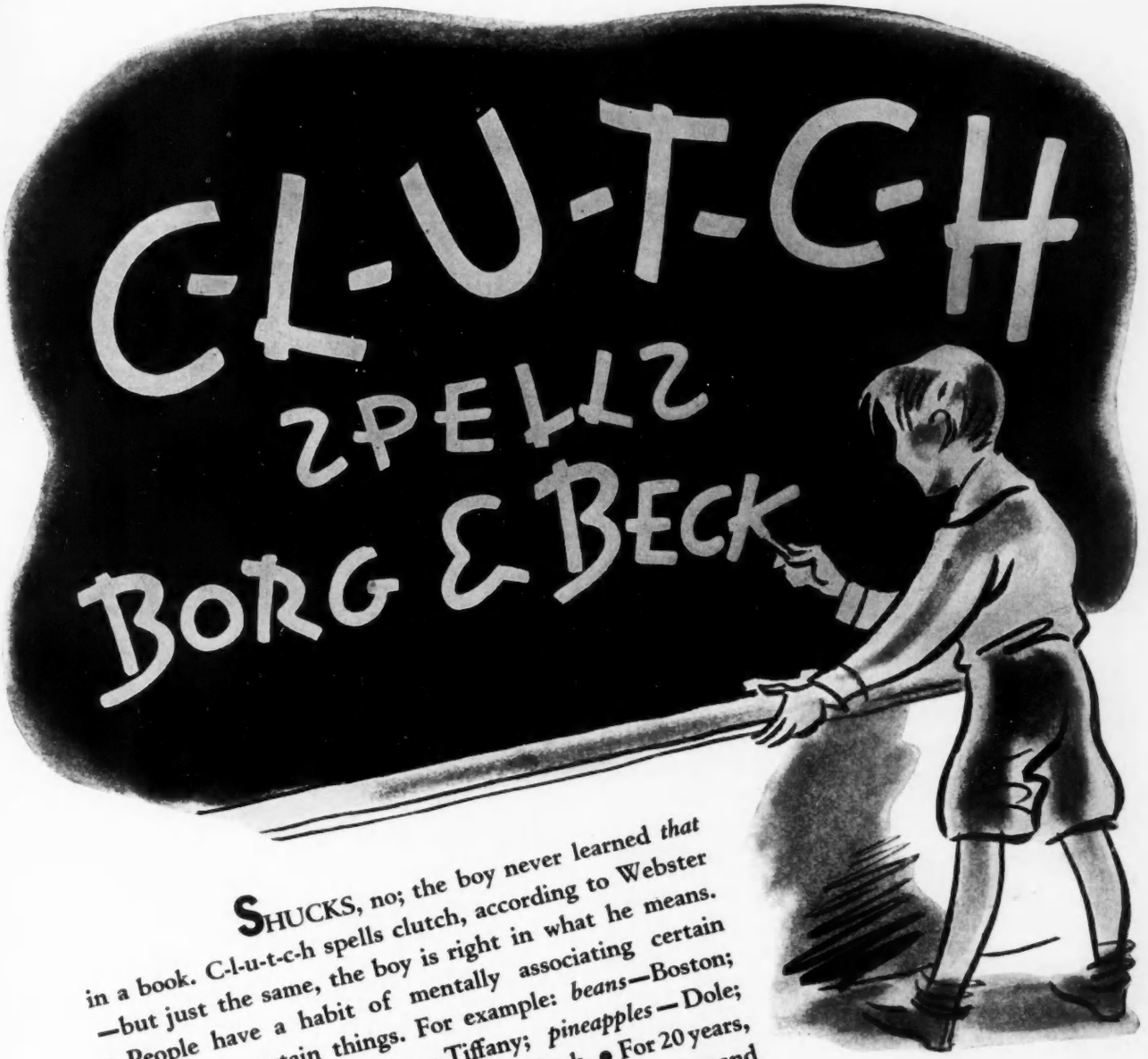
Technical Aspects of the 1934 International Touring Competition (Fundflug)

By R. Schulz and W. Pleines. Translated from *Luftwissen*, September 15 and October 15, 1934. N.A.C.A. Technical Memorandum No. 760, December, 1934; 24 pp., 23 figs. [A-3]

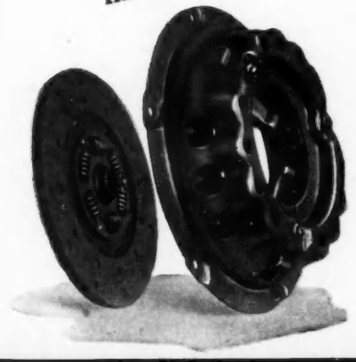
Spot Welding and Its Application to Aircraft Structure

Prepared by C. L. Hibert. Air Corps Technical Report No. 3901. Published by the Chief of the Air Corps, City of Washington, July 10, 1934; 19 pp., figures and charts. [A-5]

(Continued on page 44)



SHUCKS, no; the boy never learned *that* in a book. C-l-u-t-c-h spells clutch, according to Webster —but just the same, the boy is right in what he means. • People have a habit of mentally associating certain names with certain things. For example: *beans*—Boston; *jewelry*—Tiffany; *pineapples*—Dole; *clutches*—Borg & Beck. • For 20 years, Borg & Beck has been developing and building clutches so nearly perfect that motorists take clutch dependability for granted. The result is that automobile engineers are almost unanimous in specifying Borg & Beck clutches year after year. • We like to think that our reputation for good designing, careful manufacturing and prompt delivery was the reason why our business in 1934 set a new record.



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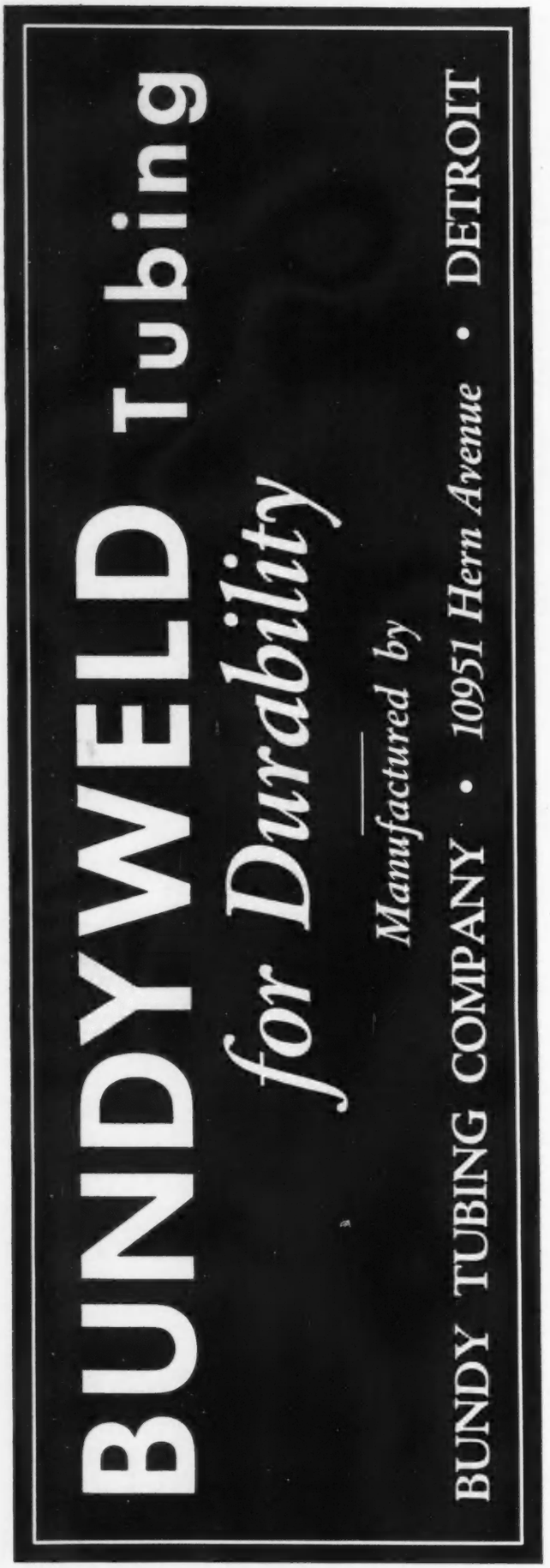

NOTES AND REVIEWS

Continued

ENGINES

The Internal Combustion Engine. Vol. II. The Aero-Engine

By D. R. Pye. Published by Oxford University Press, London, 1934; 398 pp., illustrated. [E-1]

Forming a sequel to the author's earlier volume which dealt with the basic principles of combustion and thermal efficiency in all types of internal combustion engine, this book carries on the same method of treatment in dealing with the problems to be faced by the practical designer of aero-engines or other engines of high output. Chapters are devoted to the principles of air-cooling, of superchargers and the operation of supercharged engines, carbureters, lubrication and lubricants and so forth.

The author's qualifications for presenting this subject are well known. Special credit is given by Mr. Pye to Mr. W. S. Farren who contributed Chapter II on "The Aeroplane and Its Power Plant," a discussion of the principles of flight so far as they need to be understood in order to set the aero-engine in its proper environment.

The Physical Effects of Detonation in a Closed Cylindrical Chamber

C. S. Draper. N.A.C.A. Report No. 493, 1934; 21 pp., with tables and charts. Price 10 cents. [E-1]

Effect of Shape of Discharge Valve on the Cut-Off of Fuel Spray in Injection Systems with Open Nozzles

By Fujio Nakanishi, Masaharu Itô and Kikuo Kitamura. Report No. 114 of the Aeronautical Research Institute, Tokyo Imperial University, November, 1934; 157 pp., with tables and charts. [E-1]

Le Pulso-Compressor Momy

By Pierre Léglise. Published in *L'Aéronautique*, January, 1935, p. 3. [E-1]

The piston type compressor for aircraft engines here described embodies in its driving mechanism principles similar to those of the barrel-type engine. The following new features in design are emphasized. The swash plates are inside the pistons and so formed that one complete revolution of the shaft actuates two complete piston strokes. Two pistons are located inside one cylinder, forming four compression chambers, so that in one rotation of the engine shaft eight pumping chambers are actuated. The advantages of compactness and high volumetric and mechanical efficiency are claimed.

Diesel Hand Book

By Julius Rosbloom. Published by Diesel Engineering Institute, Jersey City, N. J., Second Edition, 1935; 543 pp., illustrated. [E-3]

An enlarged second edition is now available giving useful tables, latest formulae, practical instruction on Diesel engines of both high and low-speed, auxiliaries and accessories for land, marine, locomotive, automotive, aero and portable services.

Die Auswertung der Auspuffanalyse in Kraftwagen

By A. Leye. Published in *Automobiltechnische Zeitschrift*, Dec. 25, 1934, p. 619. [E-4]

A method is here developed for the determination of combustion completeness and air excess from the chemical composition of the fuel and the CO_2 and O_2 values yielded by the exhaust gas analysis. The combustion completeness is first arrived at from a calculated CO value. The calculated value is checked by means of a combustion equation.

HIGHWAYS

Uniform Vehicle Code

Act I—Motor Vehicle Administration Registration, Certificate of Title and Antitheft Act.

Act II—Uniform Motor Vehicle Operators' and Chauffeurs' License Act.

Act III—Uniform Motor Vehicle Civil Liability Act.

Act IV—Uniform Motor Vehicle Safety Responsibility Act.

Act V—Uniform Act Regulating Traffic on Highways.

Published by the U. S. Department of Agriculture, Bureau of Public Roads, U. S. Printing Office, City of Washington, 1934. [F-1]

Tendances et Réalisations Modernes en Signalisation Ferroviaire, Routière et Urbaine

Published in *La Technique Moderne*, Jan. 15, 1935, p. 16. [F-1]

In summarizing the tendencies and current practice in highway marking and traffic control lights, the author discusses the progress in international standardization on this subject, the problems peculiar to highway marking, warning signs, traffic control signs at busy intersections and grade crossing markings.

(Continued on page 46)

FIFTY YEARS OF PROGRESS

In 1885, fifty years ago, the American Telephone and Telegraph Company was formed.

There were few telephones then and service was slow, uncertain and limited to separate communities. In that year the largest number of telephones in any one city was 8400, in New York.

New York now has 1,500,000, Chicago 800,000, Philadelphia 350,000.

From your own Bell telephone you may talk with any one of 17,000,000 other telephones in this country and most of those in foreign lands. Today, 93% of all the world's telephones are within reach of the Bell telephone in your home or office.

This year marks also the Twentieth Anniversary of the opening of the first transcontinental line, from New York to San Francisco, and the Eighth Anniversary of the opening of transatlantic service.

The work of improving Bell telephone communication is never ended . . . it goes on and on toward a constantly higher standard. Further improvements as important as those of the past half-century will come through Bell System research, manufacturing and unified operation.

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To make your telephone service dependable, 94 per cent of the Bell System's 80,000,000 miles of wire is now in storm-resisting, lead-covered cable. Sixty-five per cent of it is buried beneath the ground.

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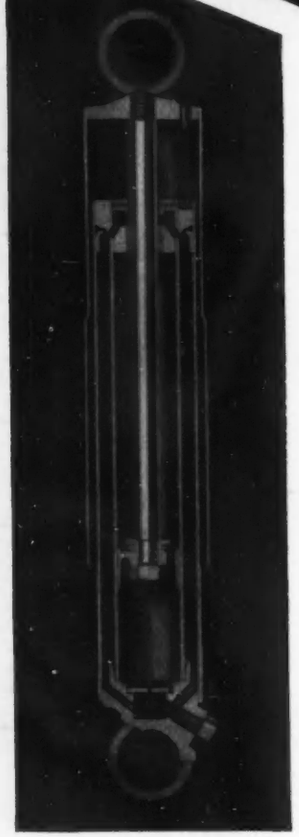

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Direct Action
Self-
Compensating
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For maximum comfort under any riding conditions, the character of the ride can be predetermined by changing the valve plates of these Spicer Shock Absorbers. An important advantage of these shock absorbers is the ease with which they can be dis-assembled. For further information, write for Bulletin No. 95.

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NOTES AND REVIEWS

Continued

Ergebnisse der Strassenbauversuche auf der 2000-Km-Fahrt 1934

By A. Liese. Published in *Automobiltechnische Zeitschrift*, Jan. 10, 1935, p. 17. [F-1]

The German Automobile Club has in recent years made its 1200 mile tour of value to road builders by ascertaining from participants their opinions on various phases of road construction. This year's questionnaire, the results of which are here published, was concerned with highway markers, lighting and surface.

Model Traffic Ordinances

Issued by the National Conference on Street and Highway Safety, Daniel C. Roper, Secretary of Commerce, Chairman. [F-4]

This leaflet consists of a model municipal traffic ordinance, a model traffic administrative ordinance, and state law provisions which might be included in the traffic ordinance, all as revised and approved by the Fourth National Conference on Street and Highway Safety, May 23-25, 1934.

MATERIAL

Influence of Chemically and Mechanically Formed Notches on Fatigue of Metals

By Dunlap J. McAdam, Jr., and Robert W. Clyne. Bureau of Standards Research Paper No. 725, 1934; 45 pp., 13 figs. [G-1]

An introductory section discusses the importance of stress concentration due to notches, as a cause of failure in service. Section II considers the effect of chemically formed notches, attention being confined to the influence of pitting caused by stressless corrosion. The general object of Section III is to determine whether composite curves of similar form may be obtained by a study of experimental data obtained by a number of investigators with mechanically formed notches. Section IV considers the relationship between notch sensitivity and other properties of metals. Section V considers the influence of notches in diminishing the advantage of superior strength. A list of selected references is included.

Inhibitors in Cracked Gasoline

By C. G. Dryer, J. C. Morrell, Gustav Egloff and C. D. Lowry, Jr. Published in *Industrial and Engineering Chemistry*, January, 1935, p. 15. [G-1]

In the belief that further work was desirable to determine the significance of accelerated testing and the validity of prediction of gasoline stability from induction period, the storage tests here reported were carried out. They were designed to obtain information regarding the relationship between induction period, rate of gum formation and storage stability of cracked gasolines.

Samples of five representative gasolines were stored in glass bottles vented to the air for 20 months. Some of the samples contained inhibitors. Among samples of any one gasoline, a relationship was found between induction period and storage life. Conclusions are also drawn as to effect of inhibitors on stability in storage.

Colloidal Graphite as an Adjunct Lubricant for Automobile Engines

By H. Higinbotham. Published in *Institution of Automobile Engineers Journal*, January, 1935, p. 79. [G-1]

A summary is here given of various researches bearing on the value of colloidal graphite additions to automotive-engine lubricants. The production of colloidal graphite is briefly discussed, as well as evidence advanced to show that its use in the lubricant results in the formation of a graphoid surface.

Tests are quoted to show the value of this graphoid surface in reducing friction, wear due to either attrition or corrosion, and seizure. Other topics are the addition of colloidal graphite to the coolant paraffin used in honing and grinding, the relation between its properties and oil sludging and its use in upper cylinder lubrication.

Internationale Alpenwertungsfahrt mit Ersatztreibstoffen

By C. Schmid. Published in *Automobiltechnische Zeitschrift*, Nov. 25, 1934, p. 580. [G-1]

A report is here given of the first international Alpine competitive tour for vehicles using fuels other than petroleum products. Carried out under the auspices of the Austrian government, it had also the official support of Switzerland and Italy. Ten vehicles fueled with coal derivatives, producer gas and alcohol participated in the ten-day tour, as did several conventional gasoline-engined vehicles entered for purposes of comparison.

(Concluded on page 48)

No doubt about it!

AMERICA WANTS HYDRAULIC BRAKING

THE vote is in. Motoring America *wants* Hydraulic Braking. If you sell motor cars you know it. You know that Hydraulic Braking is a definite, important sales asset, and that its value is steadily growing.

Consider the reasons. Hydraulic Braking gives the motorist an easy, cushioned pedal — permanent equalization of pressure—freedom from lubrication of linkage —freedom from noise. Hydraulic Braking gives the dealer low service overhead, added sales appeal and brake-contented customers. It gives the manufacturer low installation cost and high public acceptance.

Correspondence is invited.

HYDRAULIC BRAKE COMPANY
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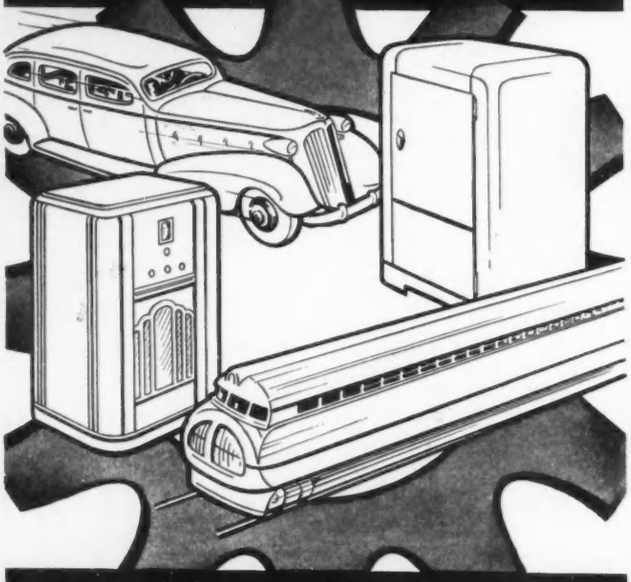

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NEW CATALOG

Just off the press—our new 1935 catalog tells you how to solve your locking problems. Also illustrates and explains other patented Shakeproof products—a truly valuable book—send for your free copy today!

IN every industry, engineers are striving to achieve new performance peaks. Faster speeds—greater efficiency—longer life, are some of the goals that they are trying to reach. That's why the demand for Shakeproof Lock Washers is constantly growing—the need for a tight, vibration-proof locking method is paramount. Be sure to try Shakeproof Lock Washers on your product—see how each twisted tooth forms a positive double-action lock that only applied pressure can release. Then realize that the power of this lock is multiplied by the number of teeth on the washer (from 6 to 20 times)—that's why you can depend on Shakeproof to hold each and every screw or nut absolutely tight! Send for testing samples today!

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Lock Washer Company

Distributors of Shakeproof Products
Manufactured by Illinois Tool Works

2507 N. Keeler Ave. Chicago, Ill.

U. S. Pat. 1,419,564—1,604,122—1,697,954—1,782,387—Other Pat. Pending—Foreign Pat.

NOTES AND REVIEWS

Concluded

MISCELLANEOUS

Noise Measurements for Engineering Purposes

By B. G. Churcher. Published in *Electrical Engineering*, January, 1935, p. 55. [H-1]

The two principles of noise measurement, the subjective and the objective, are discussed with special reference to the electrical plant. Two forms of measurement embodying the subjective principle are considered, the proposed primary standard method and the noise audiometer. A form of audiometer and technique are described.

With regard to the objective method, the evidence is said to show that the objective type of instrument now available evaluates the noise of many types of plant correctly, but that with noises predominantly harmonic in tone structure, the principle of the method is inapplicable.

Prospective Expenditures on Rolling Stock and Shops

Published in *Railway Age*, Dec. 1, 1934, p. 717. [H-1]

A reduction in train-mile costs amounting to about one-third effected by railcars is here advanced as justification for including this type of vehicle among prospective railroad purchases. A field is claimed for both single and articulated units, for the latter restricted to lines of stable traffic.

La Construction et le Fonctionnement des Automotrices sur Rail

By H. Jouffret. Published in *Journal de la Société des Ingénieurs de l'Automobile*, November, 1934, p. 2913. [H-1]

Lack of flexibility in schedules and itinerary and too great dead weight in construction are the reasons assigned for the failure of the railroads successfully to meet automotive competition. The new railcars have the advantages of lighter weight, higher speed, better acceleration and braking; in the two latter respects French vehicles are said to excel. Through railcars, higher average speed and a greater frequency in scheduled trips are thus attainable.

The work of the French special railcar commission is favorably discussed, the present and possible future number of railcars in operation is estimated, and railcar design is discussed both by individual features and the assembled vehicles of 5 different makes.

Les Trolleybus en Italie

Published in *Le Véhicule Electrique*, October, 1934, p. 49. [H-1]

Italy installed its first trackless trolley line in 1903, and has still in operation the oldest trackless trolley line in the world, dating back to 1908. Seven trackless trolley lines now employ a total of 56 vehicles. These lines and the principal features of the vehicles are described.

Torsional Vibration

By W. A. Tuplin. Published by John Wiley & Sons, Inc., New York and London, 1934; 320 pp. [H-3]

This book seeks to explain in the simplest manner those parts of the fundamentals of vibration theory which are necessary for a complete understanding of practical problems, and more particularly, to show in detail the procedure to be followed in the actual calculations.

The author introduces what he believes to be a new conception, associated with the term "torque function," and from this derives certain methods of calculation which are said to have distinct advantages over the conventional ones.

Code Restrictions on Machinery and Production

By W. H. Hopkins and J. F. Nelson. Published in *Mechanical Engineering*, January, 1935, p. 9. [H-5]

In 108 NRA codes there are 163 provisions limiting the extension and use of plant capacity and restricting industrial production. This statement summarizes the findings of the A.S.M.E. Capital-Goods Industries Committee in its investigation of restrictions on manufacturing equipment in the Codes of Fair Practice. The report here presented lists and classifies the restrictions as found in the codes for various industries.

PASSENGER CAR

Berechnungsdaten auf Grund von Betriebserfahrungen mit Jaray-Stromlinienwagen

By Stefan Fischer. Published in *Automobiltechnische Zeitschrift*, Jan. 10, 1935, p. 8. [L-1]

The author assisted in the development of a Jaray streamlined car and both in practical road tests, with and without the body attached in coasting and in high-speed runs, and in test stand measurements segregated the various items of rolling resistance and determined their total value. He here gives a brief summary of the test results.